SCIENCE

FRIDAY, APRIL 7, 1916

CONTENTS

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THE DISTANCES OF THE HEAVENLY BODIES[1]

A YEAR ago our retiring president took the members of the society into his confidence as follows:

Cognizant of the fact that my election to the presidency of the Philosophical Society a year ago obligated me to give an address of some sort one year later, I confidently waited for the inspiration that I felt would suggest a fitting subject for the occasion. The expected inspiration did not, however, materialize.

Undoubtedly because of that fact, and out of the goodness of his heart, towards the close of his address he turned to the present speaker, then presiding, and said:

I have said nothing whatever about the determination of the distances between the planets nor of the units used by astronomers in reckoning distances of the stars. . . . They form, so to speak, other chapters of the subject which I shall leave to some future ex-president of our society.

This call, I suppose, was intended to take the place of an inspiration, and, wherever I have gone during the past twelve months the call has ever been ringing in my ears. The subject of the evening is presented therefore not as a matter of choice, but from compulsion.

Before any attempt was made by the ancients to determine the distance from the earth of any celestial body, we find them arranging these bodies in order of distance very much as we know them to-day, assuming that the more rapid the motion of a body among the stars the less its distance from the earth; the stars, that were supposed to have no relative motions, were assumed to be the most distant objects.

[1] Address of the president of the Philosophical Society of Washington, March 4, 1916.

The first attempt to assign definite relative distances to any two of the bodies was probably that of Eudoxus of Cnidus who, about 370 B.C., supposed, according to Archimedes, that the diameter of the sun was nine times greater than that of the moon, which is equivalent to saying, since the sun and the moon have approximately the same apparent diameter, that the distance of the sun from the earth is nine times greater than that of the moon.

A century later, about 275 B.C., Aristarchus of Samos gave a method of determining the relative distances of the sun and moon from the earth as follows: When the moon is at the phase, first quarter or last quarter, the earth is in the plane of the circle which separates the portion of the moon illuminated by the sun from the non-illuminated part, and the line from the observer to the center of the moon is perpendicular to the line from the center of the moon to the sun. (Diagram shown.) If, at this instant, the angular separation of the sun and moon is determined, one of the acute angles of a right-angle triangle—sun, moon and earth—is known, from which can be deduced the ratio of any two of the sides, as, for instance, the ratio of the distance from the earth to the moon to that from the earth to the sun. Aristarchus gives the value of this angle as differing from a right angle by only one thirtieth of that angle, *i. e.*, it is an angle of 87°, from which follows that the distance from the earth to the sun is nineteen times that from the earth to the moon. This method of Aristarchus is theoretically correct, but, in determining the angle at the earth as being 3° less than a right angle, he made an error of about 2° 50′.

Hipparchus, who lived about 150 B.C. and was called by Delambre the true father of astronomy, attacked the problem of the distances of the sun and moon through a study of eclipses. Assuming in accordance with the result of Aristarchus that the sun is nineteen times as far from the earth as the moon, having determined the diameter of the earth's shadow at the distance of the moon and knowing the angular diameter of the moon, he found 3′ as the sun's horizontal parallax. By the sun's parallax is meant the angle at the sun subtended by the earth's semi-diameter and if $a =$ the semi-diameter of the earth, $\Delta =$ the distance to the sun, and $\pi =$ sun's horizontal parallax, the relation between these quantities is expressed by the equation (diagram shown).

$$\operatorname{Sin} \pi = a/\Delta.$$

The next attempt to determine the distance of a heavenly body was made about A.D. 150 by Claudius Ptolemy, the last of the ancient astronomers, and one whose writings were considered the standard in things astronomical for fifteen centuries. To determine the lunar parallax, he resorted to direct observations of the zenith distance of the moon on the meridian, comparing the result of his observations with the position obtained from the lunar theory. He determined the parallax when the moon was nearest the zenith, and also when it crossed his meridian at its farthest distance from the zenith. From his observations he obtained results varying from less than 50 per cent. of the true parallax (57′.0) to more than 150 per cent. of that value. According to Houzeau the definitive result of Ptolemy's work is 58.′7.

It is thus seen that the astronomers of two thousand years ago had a fairly accurate knowledge of the distance of the moon from the earth, but an entirely erroneous one of the distance of the sun, the true distance being something like twenty times that assumed by them. This value of the distance of the sun from the earth was accepted for nineteen centuries, from Aristarchus to Kepler, having been deduced

anew by such men as Copernicus and Tycho Brahe.

With the announcement by Kepler, early in the seventeenth century, of his laws of planetary motion, it became possible to deduce from the periodic times of revolution of the planets around the sun their relative distances from that body, and thus to determine the distance of the sun from the earth, by determining the distance or parallax of one of the planets.

From observations of Mars, Kepler obtained the distance of the sun from the earth as about three times that accepted up to his time. His value, however, was but one seventh of the true distance. About fifty years later Flamsteed and Cassini working independently, and using the same method as that employed by Kepler, obtained for the first time approximately the correct value of the distance of the sun from the earth. In a letter, dated November 16, 1672, to the publisher of the *Philosophical Transactions*, Flamsteed says:

> September last I went to Townley. The first week that I intended to have observed ♂ there with Mr. Townley, I twice observ'd him, but could not make two Observations, as I intended, in one night. The first night after my return, I had the good hap to measure his distances from two Stars the same night; whereby I find, that the Parallax was very small; certainly not 30 seconds: So that I believe the Sun's Parallax is not more than 10 seconds. Of this Observation I intend to write a small Tract, when I shall gain leisure; in which I shall demonstrate both the Diameter and Distances of all the Planets by Observations; for which I am now pretty well fitted.

During the two and a half centuries since Flamsteed's determination there have been more than a hundred determinations of the solar parallax by various methods. In the method used by Flamsteed, the rotation of the earth is depended upon to change the relative position of the observer, the center of the earth, and Mars. (Diagram shown.) Another method is to establish two stations widely separated in latitude, and in approximately the same longitude. At one station, the zenith distance of Mars will be determined as it crosses the meridian north of the zenith; at the other station, the zenith distance will be determined as it crosses the meridian south of the zenith. The sum of the two zenith distances minus the difference in latitude between the two stations will give the displacement of Mars due to parallax. These two methods have been successfully applied to several of the asteroids whose distances from the sun are very near that of Mars.

The nearest approach of Venus to the earth is during her transit across the face of the sun, and these occasions, four during the last two centuries, have been utilized to determine the solar parallax. Here as in the case of Mars two different methods may be used, either by combining observations at two stations widely separated in latitude, or at two stations widely separated in longitude. (Diagrams shown.)

The methods just described for obtaining the solar parallax, the geometrical methods, were made available, as has been said, by the discovery of Kepler's laws of planetary motion. Newton's discovery of the law of gravitation gave rise to another group of methods, designated as gravitational methods. The best of these is probably that in which the distance of the sun from the earth is determined from the mass of the earth, which, in turn, is determined from the perturbative effect of the earth upon Venus and Mars. This method is long and laborious, but its importance lies in the fact that the accuracy of the result increases with the time. Professor C. A. Young says:

> This is the "method of the future," and two or three hundred years hence will have superseded all the others—unless indeed it should appear that bodies at present unknown are interfering with the movements of our neighboring planets, or un-

less it should turn out that the law of gravitation is not quite so simple as it is now supposed to be.

A third group of methods of determining the distance of the sun from the earth, called the physical methods, depends upon the determination of the velocity of light in conjunction either with the time it takes light to travel from the sun to the earth obtained from observations of the eclipses of Jupiter's satellites, or with the constant of aberration derived from observations of the stars.

In August, 1898, Dr. Witt, of Berlin, discovered an asteroid, since named Eros, which was soon seen to offer exceptional opportunity for the determination of the solar parallax, as at the very next opposition, in November, 1900, it would approach to within 30,000,000 miles of the earth. At the meeting of the Astrographic Chart Congress in Paris in July, 1900, it was resolved to seize this opportunity and organize an international parallax campaign. Fifty-eight observatories took part in the various observations called for by the general plan. The meridian instruments determined the absolute position of Eros from night to night as it crossed the meridians of the various observatories; the large visual refractors measured the distance of Eros from the faint stars near it, at times continuing the measures throughout the entire night; and the photographic equatorials obtained permanent records of the position of Eros among the surrounding stars. In addition long series of observations had to be made to determine the positions of the stars to which Eros was referred.

When several years had elapsed after the completion of the observations, and no general discussion of all the material had been provided for, Professor Arthur R. Hinks, of Cambridge, England, volunteered for the work. The undertaking was truly monumental. He first formed a catalogue of the 671 stars which had been selected by the Paris Congress for observation as marking out the path of Eros from a discussion of the results obtained by the meridian instruments and from the photographic plates. This done, with these results as a basis, a larger catalogue of about 6,000 stars had to be formed from measures on the photographic plates. He was then ready to commence the discussion of the observations of Eros itself. From 1901 to 1910 there appeared in the *Monthly Notices* of the Royal Astronomical Society eight articles covering 135 pages giving the results of his labors.

From a discussion of all the photographic observations he obtained a solar parallax of $8''.807 \pm 0''.0027$, a probable error equivalent to an uncertainty of about 30,000 miles in the distance to the sun.

From a discussion of all the micrometric observations he obtained $8''.806 \pm 0''.004$.

The observations with the meridian instruments gave $8''.837 \pm 0''.0185$, a determination relatively much weaker than either of the others.

A parallax of $8''.80$, the value adopted for all the national almanacs twenty years ago, corresponds to a distance of 92,900,000 miles. At present it seems improbable that another parallax campaign will be undertaken before 1931, when Eros approaches still nearer to the earth, its least distance at that time being about 15,000,000 miles.

APPROXIMATE DISTANCES FROM EARTH TO SUN AS ACCEPTED AT VARIOUS TIMES

Date.	Distance, Miles.
275 B.C. to A.D. 1620	4,500,000
1620 Kepler	13,500,000
1672 Flamsteed	81,500,000
1916	92,900,000

When Copernicus proposed that the sun is the center of the solar system and all the planets including the earth revolve around the sun, it was at once seen that such a mo-

tion of the earth must produce an annual parallax of the stars. Tycho Brahe rejected the Copernican system because he could not find from his observations any such parallax. However, the system was generally accepted as the true one and the determination of stellar parallax or the distance of the stars became a live subject. Picard in the latter half of the seventeenth century, using a telescope and a micrometer in connection with his divided circle, showed an annual variation in the declination of the pole star amounting to 40″. In 1674 Hooke announced a parallax of 15″ for γ Draconis. About this same time Flamsteed announced a parallax of 20″ for α Ursæ Minoris, but J. Cassini showed that the variations in the declination did not follow the law of the parallax.

The period which we have now reached is so admirably treated by Sir Frank W. Dyson, Astronomer Royal, in his Halley lecture delivered at Oxford on May 20, 1915, that I ask your indulgence while I quote rather freely from that source.

Thus in Halley's time, it was fairly well established that the stars were at least 20,000 or 30,000 times as distant as the sun. Halley did not succeed in finding their range, but he made an important discovery which showed that three of the stars were at sensible distances. In 1718 he contributed to the Royal Society a paper entitled "Considerations of the Change of the Latitude of Some of the Principal Bright Stars." While pursuing researches on another subject, he found that the three bright stars—Aldebaran, Sirius and Arcturus—occupied positions among the other stars differing considerably from those assigned to them in the "Almagest" of Ptolemy. He showed that the possibility of an error in the transcription of the manuscript could be safely excluded, and that the southward movement of these stars to the extent of 37′, 42′ and 33′—*i. e.*, angles larger than the apparent diameter of the sun in the sky—were established. . . .

This is the first good evidence, *i. e.*, evidence which we now know to be true, that the so-called fixed stars are not fixed relatively to one another. It is the first positive proof that the distances of the stars are sensibly less than infinite.

At the time of the appearance of Halley's paper there was coming into notice a young astronomer, James Bradley, then twenty-six years old. He was admitted to membership in the Royal Society the same year that Halley's paper was presented. He was exceedingly eager to attack the problem of the distances of the stars. At length the opportunity presented itself. To quote again from Sir Frank Dyson:

Bradley designed an instrument for measuring the angular distance from the zenith, at which a certain star, γ Draconis, crossed the meridian. This instrument is called a zenith sector. The direction of the vertical is given by a plumb-line, and he measured from day to day the angular distance of the star from the direction of the vertical. From December, 1725, to March, 1726, the star gradually moved further south; then it remained stationary for a little time; then moved northwards until, by the middle of June, it was in the same position as in December. It continued to move northwards until the beginning of September, then turned again and reached its old position in December. The movement was very regular and evidently not due to any errors in Bradley's observations. But it was most unexpected. The effect of parallax—which Bradley was looking for—would have brought the star farthest south in December, not in March. The times were all three months wrong. Bradley examined other stars, thinking first that this might be due to a movement of the earth's pole. But this would not explain the phenomena. The true explanation, it is said, although I do not know how truly, occurred to Bradley when he was sailing on the Thames, and noticed that the direction of the wind, as indicated by a vane on the mast-head, varied slightly with the course on which the boat was sailing. An account of the observations in the form of a letter from Bradley to Halley is published in the *Philosophical Transactions* for December, 1728:

"When the year was completed, I began to examine and compare my observations, and having pretty well satisfied myself as to the general laws of the *phenomena*, I then endeavored to find out the cause of them. I was already convinced that the apparent motion of the stars was not owing to the nutation of the earth's axis. The next

thing that offered itself was an alteration in the direction of the plumb-line with which the instrument was constantly rectified; but this upon trial proved insufficient. Then I considered what refraction might do, but here also nothing satisfactory occurred. At length I conjectured that all the *phenomena* hitherto mentioned, proceeded from the progressive motion of light and the earth's annual motion in its orbit. For I perceived that, if light was propagated in time, the apparent place of a fixed object would not be the same when the eye is at rest, as when it is moving in any other direction than that of the line passing through the eye and the object; and that, when the eye is moving in different directions, the apparent place of the object would be different."

When Bradley's observations of γ Draconis were corrected for aberration, they showed, according to himself, that the parallax of that star could not be as much as 1".0, or that the star was more than 200,000 times as distant from the earth as the sun.

On December 6, 1781, there was read before the Royal Society a paper by Mr. Herschel, afterwards Sir William, on the "Parallax of the Fixed Stars." We read:

The method pointed out by Galileo, and first attempted by Hook, Flamstead, Molineaux and Bradley, of taking distances of stars from the zenith that pass very near it, though it failed with regard to parallax, has been productive of the most noble discoveries of another nature. At the same time it has given us a much juster idea of the immense distance of the stars, and furnished us with an approximation to the knowledge of their parallax that is much nearer the truth than we ever had before. . . .

In general, the method of zenith distances labours under the following considerable difficulties. In the first place, all these distances, though they should not exceed a few degrees, are liable to refractions; and I hope to be pardoned when I say that the real quantities of these refractions, and their differences, are very far from being perfectly known. Secondly, the change of position of the earth's axis arising from nutation, precession of the equinoxes, and other causes, is so far from being completely settled, that it would not be very easy to say what it exactly is at any given time. In the third place, the aberration of light, though best known of all, may also be liable to some small errors, since the observations from which it was deduced laboured under all the foregoing difficulties. I do not mean to say, that our theories of all these causes of error are defective; on the contrary, I grant that we are for most astronomical purposes sufficiently furnished with excellent tables to correct our observations from the above mentioned errors. But when we are upon so delicate a point as the parallax of the stars; when we are investigating angles that may, perhaps, not amount to a single second, we must endeavor to keep clear of every possibility of being involved in uncertainties; even the hundredth part of a second becomes a quantity to be taken into consideration.

Herschel then proceeds to advocate selecting pairs of stars of very unequal magnitude and whose distance apart is less than five seconds, and making very accurate micrometric measures of this distance from time to time. The first condition should give, in general, stars very unequally distant from the earth, so that the changing perspective as the earth revolves in her orbit would give a variation of the apparent distance between the stars, while the small distance, less than five seconds, would eliminate from consideration entirely any effect upon this distance of the uncertainties in refraction, precession, nutation, aberration, etc. Herschel had already commenced the cataloguing of such double stars and in January, 1782, submitted to the Royal Society a catalogue of 269. This work did not enable Herschel to determine the distance of the stars but did enable him to demonstrate that there exist pairs of stars in which the two components revolve the one around the other. In twenty years he had found fifty such pairs.

Coming forward another generation, that is, to a time a little less than a hundred years ago, we find Pond, then Astronomer Royal, writing

The history of annual parallax appears to me to be this: in proportion as instruments have been imperfect in their construction, they have misled observers into the belief of the existence of sen-

sible parallax. This has happened in Italy to astronomers of the very first reputation. The Dublin instrument is superior to any of a similar construction on the continent; and accordingly it shows a much less parallax than the Italian astronomers imagined they had detected. Conceiving that I have established, beyond a doubt, that the Greenwich instrument approaches still nearer to perfection, I can come to no other conclusion than that this is the reason why it discovers no parallax at all.

Within fifteen years after this statement by Pond, observations had been obtained which showed a measurable parallax of three different stars. The announcements of these results, each by a different astronomer, were practically simultaneous.

W. Struve, using a filar micrometer, determined the distance of α Lyræ from a small star about 40″ distant on 60 different days over a period of nearly three years. He obtained a parallax of 0″.262 ± 0.″025. Bessel, using his heliometer, determined the distance of 61 Cygni from two small stars distant about 500″ and 700″, respectively. He obtained for this star a parallax of 0″.314 ± 0″.020. Henderson, using determinations of the position of α Centauri by meridian instruments, deduced a parallax of 1″.16 ± 0″.11. All three of these results were announced in the winter of 1838–39, and indicate that the three stars are distant from the earth about 750,000, 650,000 and 200,000 times the distance of the sun from the earth.

The accompanying table exhibits the observed displacement of 61 Cygni by monthly means as given by Main from Bessel's observations. The last column gives the computed displacement on the assumption of a parallax of 0″.314. The reality of the parallax is seen at a glance.

In 1888, fifty years after the first determination of what we now know to be a true stellar parallax, Young, in his General Astronomy, gives, in a list of known stellar parallaxes, 28 stars and 55 separate determinations. Within the next ten years the number of stars whose parallaxes had been determined about doubled, due principally to the work of Gill and Elkin.

PARALLAX OF 61 CYGNI

Mean Date	Observed Displacement ″	Computed from 0″.514 ″
1837 August 23	+ 0.20	+ 0.18
September 14	+ 0.10	+ 0.08
October 12	+ 0.04	— 0.05
November 22	— 0.21	— 0.22
December 21	— 0.32	— 0.27
1838 January 14	— 0.38	— 0.27
February 5	— 0.22	— 0.23
May 14	+ 0.24	+ 0.20
June 19	+ 0.36	+ 0.28
July 13	+ 0.22	+ 0.28
August 19	+ 0.15	+ 0.19
September 19	+ 0.04	+ 0.06

Probably the most extensive piece of stellar parallax work in existence is that with the Yale heliometer. The results to date were published in 1912 and contained the parallaxes of 245 stars, the observations extending over a quarter of a century, the entire work having been done by three men, Elkin, Chase and Smith. In selecting a list of stars for parallax work an effort is made to obtain stars which give promise of being nearer than the mass of stars. At first the brighter stars were selected, and then those with large proper motions. The Yale list of 245 stars contains all stars in the northern heavens whose annual proper motion is known to be as much as 0″.5. Of these 245 stars, 54 are given a negative parallax. A negative parallax does not mean, as some one has expressed it, that the star is "somewhere on the other side of nowhere," but such a result may be attributed to the errors of observation or to the fact that the comparison stars are nearer than the one under investigation. It is safe to say, however, that

somewhat more than half of the 245 stars have a measurable parallax.

Another series of stellar parallax observations, comparable in extent with the one just mentioned, is that of Flint at the Washburn Observatory. This series includes 203 stars and extended from 1893 to 1905. These observations were made with a meridian circle, but not after the method of a century ago. The observations were strictly differential, the general plan being to select two faint comparison stars, one immediately preceding and the other immediately following the parallax star, and to determine the difference in right ascension, the observation of the three stars occupying about 5 minutes. Here as in the case of the Yale heliometer work a large proportion of the resulting parallaxes are negative; somewhat more than half, however, were found to have a measurable parallax. The average probable error of a parallax was the same in each of these two pieces of work, about 0''.03. The progress of the work during the last two or three generations is given in the following table, which contains also a brief statement of the discoveries made during the preceding century, due chiefly to efforts to measure stellar parallaxes.

APPROXIMATE NUMBER OF KNOWN STELLAR PARALLAXES

Date	Astronomer	Number of Stars with Known Parallaxes	Discoveries
1718.	Halley	No parallax	Proper motion.
1728.	Bradley	No parallax	Aberration.
1750.	Bradley	No parallax	Nutation.
1790.	Herschel	No parallax	True binary systems.
1838.		3	
1888.		28	
1898.		50 to 60	
1916.		200 to 300	

A generation ago photography entered the field of stellar parallax work, and has outdistanced all the previously employed methods for efficiency. In 1911, two publications appeared giving the results of photographic stellar parallax work, one by Russell, giving the parallaxes of forty stars from photographs taken by Hinks and himself at Cambridge, England, the other by Schlesinger, giving the parallaxes of twenty-five stars from photographs taken mostly by himself at the Yerkes Observatory, Williams Bay, Wisconsin. In speaking of these two series of observations, Sir David Gill said,

> On the whole, the Cambridge results, when a sufficient number of plates have been taken, and when the comparison stars are symmetrically arranged, give results of an accuracy which, but for the wonderful precision of the Yerkes observations, would have been regarded as of the highest class.

Schlesinger has shown that with a telescope of the size and character of the Yerkes instrument

> the number of stellar parallaxes that can be determined per annum, with an average probable error of 0.''013, will in the long run be about equal to the number of clear nights available for the work.

In other words, the Yerkes 40-inch equatorial used photographically determines stellar parallaxes with one tenth the labor required with a heliometer and with twice the accuracy.

In July, 1913, stellar parallax work was undertaken with the 60-inch reflector of the Mount Wilson Solar Observatory, and at the meeting of the American Astronomical Society at San Francisco in August, 1915, a report on that work was made. The parallaxes of thirteen stars had been determined, with a maximum probable error of 0''.010 and an average probable error of less than 0''.006, giving twice the accuracy of the Schlesinger results with the Yerkes 40-inch and from three to five times that obtained fifteen years ago. What may we not expect when the 100-inch reflector gets to work on Mt. Wilson.

At the meeting of the American Astronomical Society to which reference has just been made, two other observatories reported upon their stellar parallax work. Lee and Joy of the Yerkes Observatory reported the parallaxes of nine stars with a maximum probable error of 0''.014 and an average probable error of 0''.010, and Mitchell, of Leander McCormick Observatory, reported the parallaxes of eleven stars with a maximum probable error of 0''.012 and an average probable error of 0''.009.

The progress made in the accuracy of parallax results is shown at a glance in the following table.

THE ACCURACY OF STELLAR PARALLAX DETERMINATIONS

Date	Instrument	Probable Error	Observers
		"	
1838	Dorpat refractor	0.025	Struve.
1838	Königsberg heliometer	0.02	Bessel.
1880–1898	Cape heliometer	0.017	Gill and assistants.
1888–1912	Yale heliometer	0.03	Elkin, Chase, and Smith.
1893–1905	Washburn meridian circle	0.03	Flint.
	Photographic Results		
1910	Yerkes refractor	0.013	Schlesinger.
1915	Yerkes refractor	0.010	Lee and Joy.
1915	Leander McCormick refractor	0.009	Mitchell.
1915	Mt. Wilson 60-inch reflector	0.006	Van Maanan.

From these results it appears that any star whose parallax is as much as 0''.02, *i. e.*, whose distance from the earth is less than ten million times that from the earth to the sun, should give a positive result when subjected to the treatment now employed in parallax investigations, and as eight or ten observatories are devoting their energies to stellar parallax work at present, the combined programs containing over 1,000 different stars, we ought to have soon lists of at least a few thousand stars whose parallaxes are known where our present ones contain but a few hundred.

W. S. EICHELBERGER

U. S. NAVAL OBSERVATORY

METHODS OF TEACHING ELECTRICAL ENGINEERING[1]

IN the American engineering schools must be recognized professional schools of distinctly advanced grade corresponding to the schools of the more ancient professions of medicine, law and theology. With marked sympathy for artisanship in its most useful forms, their practises and ideals are fully distinct from schools of skilled artisanship such as are in certain countries known as engineering schools; and the preparatory studies required to make students eligible to enter their courses of instruction definitely contain much work in mathematics and the sciences, in addition to an optional range of studies in the modern languages, economics and civics, history and the classics. That is, the American engineering schools are professional schools of university order, as the term university is known internationally. This form of the engineering schools in America is the result of experience and development, which has brought them to educational characteristics much resembling those of the Ecole des Ponts et Chaussees and the Ecole Polytechnique of Paris.

Originating with the third decade of the nineteenth century, the earlier American engineering schools first treated of what we now term "civil engineering," and "mechanical engineering" and "mining engineering" were later joined to the fixed curricula. It was not until 1882 that a formal course of "electrical engineering" was established, and curiously enough, this was done independently and almost

[1] Pan-American Scientific Congress, Washington, D. C., January 4, 1916.

simultaneously in two of our most noted engineering schools, Massachusetts Institute of Technology and the engineering school of Cornell University. In each of these, the first graduates completed their courses in June, 1885. Thereafter, formal courses of instruction in electrical engineering were established in most of the educational centers supporting engineering schools, until there are now ninety-five such courses in the land, embracing over 8,000 students, and from whom over 19,000 students have graduated. These courses can not be accepted as of equal rank, but it may be reasonably claimed for all that certain methods of instruction have proved serviceable and are given more or less full acceptance, depending upon the stability and strength of the organization, and the thoroughness of preparation which may be required of entering students.

Fundamentally there are two principles lying at the root of the methods of our best engineering schools, which are:

1. It is the business of these schools to train young men into fertile and exact thinkers guided by common sense, who have a profound knowledge of natural laws and of the means for utilizing natural forces for the advantage of man and the advancement of civilization. In other words, it is the business of engineering schools to produce, not finished engineers, but young men with a great capacity for becoming engineers, the goal being attained by the graduates only after years of development in the school of life.

2. The problem facing the engineering schools is more particularly a problem of pedagogy rather than a problem of the engineering profession. The problem is *how to properly train the students' powers to the stated purposes.* It must be grappled with all the directness and force of the engineers' best efforts, but it can not be solved as solely relating to the engineering profession.

Turning now toward electrical engineering, it is to be observed that electrical engineering demands industrial engineers—men with an industrial training of the highest type, competent to conceive, organize and direct extended industrial enterprises of broadly varied character. These men must be keen, straightforward thinkers, who see things as they are and who are not to be misled by fancies; they must have an extended, and even profound, knowledge of natural laws (more particularly of those relating to energy and its transformations), and an extended knowledge of the useful applications of these laws; and they must be acquainted with business methods, the affairs of the business world, and with the ways of our fellow-men.

Some of our colleagues may ask "What is electrical engineering, that it demands these things of its followers?" I will answer. Electrical engineering is that branch of the profession which deals with the generation of power, primarily from fuel or water, its conversion into electrical power which may be transmitted and distributed at will for the service of the industrialist and the householder, and, for its fullest service, electrical engineering must embrace the principles and fundamental practises underlying all the great industries and activities which it serves, and it must not shirk the controlling problems of illumination. Electrical engineering is now master of the methods of national and international rapid intercommunication, of local transportation, of ready transmission of water or steam power to a distance, of a safe and convenient method of artificial illumination, and its service in the industries is constantly enlarging, but is already probably incalculable. This is a vast field of science in the industries, which brings under

requisition the problems of mechanics, the characteristics and uses of materials and their correct application to the building of actual structures, the laws of kinematics and the processes of designing and using machinery, the special principles of hydraulics and thermodynamics and the manner in which they enter into the design, construction and operation of machines, and the manner in which they affect the usefulness of machines and the efficiencies of various industries; and it brings into association with all these the specific principles of electricity and magnetism and the ways in which these principles may be used in practise.

It is only with such definitions of the field of electrical engineering and the scope of engineering education in mind that one can truly approach a discussion of "methods" of teaching electrical engineering. Lacking such definitions, the whole connotative picture is vague, indefinite, and lacking in guide posts. Given such definitions, the problem obtains definiteness and reasonable precision. The word method then may be applied. These definitions or ideals are therefore fundamental to this address. With them as guides the word "method" has a meaning and leads directly to the proposition that electrical engineering instruction must be bilateral in character, dealing first with processes of direct logic applied in mathematical forms to the solution of problems, and second with processes of reasoning by balance of evidence such as are characteristic of the discussion of economic principles or historical sequences. These two processes of reasoning hold nearly equal importance in electrical engineering, in which respect this branch of engineering differs widely from, for instance, mechanical engineering, in which a great part of the mental processes of its practitioners must be by balance of evidence because the problems are commonly of a complexity which has not yet yielded to methods of rational analysis, thus leaving empirical methods the only resort. Thus, the design of a cast-iron bed for a great engine lathe deals with a material of unhomogeneous character which is put under tension, compression and shear, in a physical shape for which the stresses do not yield directly to mathematical analysis on account of the complexity of the form which is imposed by the requirements of convenience in operating the complete machine. In contrast to this, most of the engineering problems which relate purely to electricity and magnetism partake of the character of problems of hydrodynamics and yield directly to rational processes of analysis, *i. e.*, to assault by direct logic. In electrical engineering teaching, it is largely the economic aspects of the problems, or the problems coming in from the collateral branches of engineering on account of the intimacy with which the electrical engineer must deal with the numerous branches of mechanical industry, which call for empirical methods and reasoning by balance of evidence. These are important, and therefore the methods of teaching in electrical engineering must be bilateral, as already said, first to give the student power in direct reasoning and in designing by so-called "rational" processes, and second to give him power in reasoning by balance of evidence and in designing by so-called "empirical" processes. Along with this goes hand in hand instruction of the student in nature's laws and their relations to each other, and instruction in the applications of the methods of reasoning to minor but none the less truly engineering problems. The laboratory is a living force in such instruction, and in it the student must be substantially thrown on his own resources to execute the tests or investigations assigned to him, or

much of the merit of the instruction is lost. It is obvious that in carrying out the methods of instruction here laid down, mathematics, chemistry, physics and applied mechanics are central components of the curriculum; but history and economics have an important part.

Highly developed powers of observation and induction go far to develop a man's success in electrical engineering, as in most other professional branches, and also in those branches of business that are of leading moment. This is a collateral reason why chemistry, physics, mathematics and applied mechanics are such important studies for electrical engineers. They teach their sane followers to observe closely and accurately and to draw correct conclusions from the observed premises. But an industrial engineer must also have broadly humanistic sentiments and sympathies, and he must be prepared to reason by balance of evidence from imperfect premises. These things being facts of every-day observation, what humanistic studies can we rightfully exclude from the list useful as preparation for engineering professional life, and what methods of teaching can we exclude provided only that they are directed to the teaching of the principles of science and their applications, and do not resort mainly to descriptive processes? Our solicitude need only be exercised to see that sufficient of the mathematical and physical sciences, the historical and economic studies, and the languages make constituent parts of the curriculum; and that the spirit and order in which these are studied is right. The sciences, historical and economic studies, and languages are well represented in the curricula of many of our engineering schools, but there is still a failure to impress on the students' minds that the economic subjects are intimately related with the work of the profession.

Most American engineering schools have undergraduate curricula of four years' duration. To these come large numbers of young men from the high schools and fitting schools, mostly from seventeen to nineteen years of age. They are commonly well equipped with physical vigor and latent mental strength, but they have not yet reached mental maturity. They can not be plunged without loss into a position of complete self-reliance in their processes of study, but commonly profit from a guiding hand which shows the way to self-reliance. It is only after a couple of years of the vigorous life of the engineering schools that our American young men can profit fully by laboratory work where they are thrown mostly upon their own resources; but, having reached this stage, their progress in self-reliance and effectiveness for solving minor engineering problems go hand in hand under the stimulus of a liberal method exercised by the teachers. The more mature graduates of colleges of arts gain an equal independence and effectiveness in less time.

Bringing into the midst of such laboratory classes the additional stimulus of professional research carried on by postgraduate students who are candidates for higher degrees (Master of Science and Doctor of Engineering) and by paid research assistants, as is done in the electrical engineering laboratories of the Massachusetts Institute of Technology, introduces a final factor of pedagogical method that bids fair to make the experiment an ideal success. This plan is there coupled with the classification of students, without reflection on any, in groups according to their powers, so that the quickest to assimilate may go forward as rapidly as their powers permit, absorbing collateral matter by the way, while the slower to assimilate may cover all necessary ground at a pace which affords them

adequate thoroughness. The test of such methods by time, in the American engineering schools, is not yet complete. Indeed the last steps are quite young in our practise; but they stand high by *a priori* tests, and the few years' trial thus far made indicates an ideal result from the interassociation in the same laboratory of the undergraduate laboratory instruction by problems and the postgraduate laboratory research.

DUGALD C. JACKSON

MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

THE JOSEPH A. HOLMES SAFETY ASSOCIATION

MENTION has already been made in the columns of SCIENCE of the movement to start a memorial to the late Dr. Joseph A. Holmes and an account of the preliminary meeting of representatives of different national associations was given in the same article.[1]

The first meeting of the permanent association was held in the U. S. Bureau of Mines, Washington, on March 4 last. The following organizations were represented:

American Institute of Mining Engineers, Hennen Jennings.
American Mining Congress, Dr. David T. Day.
American Federation of Labor, A. E. Holder.
Mining and Metallurgical Society, Dr. George Otis Smith.
American Society of Mechanical Engineers, General W. H. Bixby.
American Institute of Electrical Engineers, John H. Finney.
American Electro-Chemical Society, Dr. F. G. Cottrel.
American Association for the Advancement of Science, Dr. L. O. Howard.
American Chemical Society, S. S. Voorhees.
Geological Society of America, Dr. Joseph Hyde Pratt.
National Academy of Sciences, Dr. David White.
American Red Cross Society, Dr. Robert U. Patterson.
Western Federation of Miners, Joseph D. Cannon.
Mine Inspectors Institute, J. W. Paul.
Society for the Promotion of Engineering Education, Professor O. P. Hood (vice Professor Wadsworth).

[1] See SCIENCE, Vol. XLIII., No. 1101, February 4, 1916, pp. 164–165.

Letters of regret were received from the following:

United Mine Workers of America, William Green.
National Safety Council, H. M. Wilson.
American Forestry Association, P. Risdale.
American Society of Testing Materials, A. W. Gibbs.

The permanent organization was effected under the name of the Joseph A. Holmes Safety Association and the following officers were elected:

President, the Chief of the U. S. Bureau of Mines (Mr. Manning).

First Vice-president, the Secretary of the Smithsonian Institution (Dr. Walcott).

Second Vice-president, the President of the American Federation of Labor (Mr. Gompers).

The members of the executive committee to serve with the other officers were elected as follows:

Mr. Hennen Jennings, representing the American Institute of Mining Engineers.
Dr. John A. Brashear, of Pittsburgh.

The present functions of the association were formulated as follows:

1. That annually the association shall make one or more awards with honorariums to be known as "The Holmes Award" for the encouragement of those originating, developing and installing the most efficient safety devices, appliances or methods, in the mining, quarrying, metallurgical and mineral industries during the previous year, these awards to be the result of reports and investigations made by the secretary and the representatives of the association.

2. From time to time the association shall also make suitable awards for personal heroism or distinguished service or the saving of life in any branch of the mining, quarrying, metallurgical and mineral industries.

3. Once a year a meeting of the association shall be held in the city of Washington at which all awards will be publicly announced.

CONVOCATION WEEK MEETING AND THE AMERICAN CHEMICAL SOCIETY

THE council of the American Chemical Society has by a vote of 61 to 31 declined to

reconsider the vote fixing the annual meeting of the society in September. The circumstances of the case are explained in the following letter from the secretary of the society, Dr. Charles L. Parsons, addressed to the members of the council on March 2:

On February 14 a letter was received from Professor W. A. Noyes moving reconsideration of the recent vote selecting the date of September 25, 1916, for the time of our annual meeting rather than Convocation Week in December. Under vote of the council [*Proc.*, 1912, p. 43], it is necessary that the president certify to the urgency of this vote before it can be sent to the council. After some correspondence between Professor Noyes and President Herty, I am this morning in receipt of a letter from President Herty certifying to the urgency of the matter, and Professor Noyes's motion to reconsider is accordingly submitted to you for your opinion. Professor Noyes's motion and President Herty's letter to me regarding the matter follow:

"February 10, 1916.

"PROFESSOR C. L. PARSONS,
Washington, D. C.

"*Dear Professor Parsons:* In the recent vote of the council on the date of the fall or winter meeting of the American Chemical Society I voted in favor of the September date in order that I might move a reconsideration of the question. I can not believe that the members of the council, in voting as they have, gave due consideration to the following points which favor the December date:

"1. A plan has been carefully formed to bring all of the scientific interests of the country together in one city once in five years. The December date was set in order to carry out this plan for the first time. It seems only fair that the chemists of the country should cooperate in carrying out this important scheme.

"2. The date in September which is proposed is at a time when practically all of the professors and teachers in our colleges and universities are busy with the opening of the year's work and very few of this class of our members would find it possible to attend the meeting.

"I move, therefore, that the motion fixing the date of the meeting in September be reconsidered.

"I also move that in case the motion to reconsider carries the fixing of the date of the meeting be left to the directors, or, if they prefer, postponed till the April meeting of the council.

"Very respectfully,
"W. A. NOYES"

"February 29, 1916.

"DR. CHARLES L. PARSONS, *Secretary*,
American Chemical Society,
Box 505, Washington, D. C.

"*My dear Dr. Parsons:* In the recent letter ballot of the council, held for the purpose of advising the president and secretary as to the wishes of the council regarding the time for holding the 1916 annual meeting, Dr. W. A. Noyes voted in favor of the September date in order to move a reconsideration. He now so moves, with the addition that in case of reconsideration the matter be left to the decision of the directors.

"Under the action of the council at the 1911 Washington meeting it becomes my duty to pass upon the urgency of this motion.

"While simultaneous action on the two motions is somewhat unparliamentary, nevertheless in view of the desirability of settling this matter as promptly as possible, I beg to certify to the urgency of Dr. Noyes's motion for reconsideration, and request that you will submit the matter to the council immediately for letter ballot.

"I regret that I can not agree with the author of the motion in his desire that the annual meeting this year should be held in December, rather than in September as has been decided by the votes of so large a proportion of the council.

"Under normal conditions I would favor most heartily the policy of meeting quadrennially with the American Association for the Advancement of Science. At the Cincinnati meeting I spoke most earnestly in behalf of this policy, but this is an entirely different world from what it was at that time.

"As a result of the European war chemistry has received a tremendous impulse in this country; the general public has been aroused to its importance to the welfare of the country; and this year of all others it is extremely desirable that we should have at our annual meeting the largest gathering of chemists that this country has ever known, for there are many problems, the solution of which demands personal conferences by men from every section of the country. There is need for the presence of both the men from the universities and the men of the industries at such conferences, and there is need of the greatest legitimate publicity of our work and aims.

"I deeply regret that it was found absolutely impossible to hold the Second National Exposition of Chemical Industries during Convocation Week. Every effort was made to do so, but all of these efforts failed through inability to secure a suitable building during that week. The exposition must be held in September. If, therefore, we should decide to hold our annual meeting in December, I am confident that it would result in a large portion of our membership attending the exposition and failing to attend the meeting of the society. This would mean a very great loss in this particular year to the prestige and usefulness of the society. The opportunity of a lifetime is in our hands. It seems to me that we would be very unwise to divide our strength just at the time when we have so wonderful an opportunity for increasing it.

"Should the council vote against reconsideration, members of the society connected with universities would not be thereby necessarily prevented from attending the annual meeting. It seems reasonable that university authorities would gladly give leave-of-absence to members of chemistry staffs in those institutions which open on or before September 25, and certainly the departments of chemistry in all of our universities would have much to gain from a meeting held in conjunction with the Second National Exposition of Chemical Industries. "Sincerely yours,

"CHAS. H. HERTY,
"*President*"

FIRST MEETING OF THE PACIFIC DIVISION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE first meeting of the Pacific Division of the American Association for the Advancement of Science will be held in San Diego, California, between the dates, August 9 and 12, 1916. The plans for this meeting include four public addresses upon important scientific subjects of general interest. The first of this series of addresses will be that of the president of the division, Dr. W. W. Campbell, director of the Lick Observatory, Mount Hamilton, on Wednesday evening, August 9, and will be entitled "What we know about Comets." This address will be followed by a reception to visiting scientists. The three other public addresses will occur on Thursday and Friday evenings, August 10 and 11, and on the afternoon of one of the days set aside for the meeting. Addresses will be given by Dr. Barton W. Evermann, director of the Museum of California Academy of Sciences, and by Dr. F. F. Wesbrook, president of the University of British Columbia.

Thirteen scientific societies of the Pacific coast region are now affiliated with the Pacific Division and it is expected that many of these societies, together with other scientific societies of the same region will participate in the San Diego meeting. Sessions of these societies will be held on Thursday and Friday, August 10 and 11, and at least one day of the period of the meeting, Saturday, August 12, will be reserved for excursions, which will be both of general and special scientific interest.

The Channel Islands and the region of southern California present a number of extremely interesting geological features. This region is also unique botanically and zoologically. Materials of southwestern ethnology and archeology are to be found among the Indian reservations and remains of Spanish settlements in southern California. The excursions which are to be arranged at the time of the San Diego meeting, will make accessible as many as possible of these interesting features. Among other excursions which may be taken en route to or from the San Diego meeting are visits to the astronomical observatories at the Lick Observatory on Mount Hamilton, near San Jose, and the Mount Wilson Solar Observatory, near Pasadena.

Special significance centers upon this meeting of the Pacific Division of the American Association at San Diego, since this is the first of a series of meetings which it is planned to hold annually under these auspices in the educational centers of the Pacific coast. Additional interest is given to this occasion by the Panama-California Exposition at San Diego which illustrates in its exhibits the resources of the southwest and includes a series of unusually fine collections concerning the history of man.

Preceding the San Diego meeting of the Pacific Division the first assembly in science

will be held at the Scripps Institution for Biological Research at La Jolla, near San Diego, from June 26 to August 5. The Marine Biological Station of the University of Southern California at Venice and the Laguna Beach Marine Laboratory of Pomona College will also be open throughout the summer. At Pacific Grove on Monterey Bay the Marine Laboratory of Stanford University will be open during the greater part of the summer, and will offer a summer session which will begin May 22, continuing for six weeks.

The general plans for the San Diego meeting are in the hands of the officers and executive committee of the division, which are as follows:

President, W. W. Campbell, Lick Observatory, Mount Hamilton, California.

Vice-president, D. T. MacDougal, Desert Botanical Laboratory, Tucson, Arizona.

Secretary-Treasurer, Albert L. Barrows, University of California, Berkeley.

Executive Committee: D. T. MacDougal, chairman, Desert Botanical Laboratory, Tucson, Arizona; W. W. Campbell, *ex-officio*, Lick Observatory, Mount Hamilton, California; Edward C. Franklin, Stanford University, California; Theodore C. Frye, University of Washington, Seattle; C. E. Grunsky, San Francisco, California; George E. Hale, Mount Wilson Solar Observatory, Pasadena, California; Vernon L. Kellogg, Stanford University, California; A. C. Lawson, University of California, Berkeley; E. P. Lewis, University of California, Berkeley.

Plans for meetings in special branches of science are in charge of the societies representing these several branches and the arrangements at San Diego are to be made for the meeting by a local committee of which Dr. Fred Baker, of Point Loma, is the chairman. Railroad and steamer rates for attendance at this meeting will be announced later.

SCIENTIFIC NOTES AND NEWS

Dr. John A. Brashear, president of the American Society for Mechanical Engineers, was given the doctorate of laws at the Charter Day exercises of the University of Pittsburgh on March 20. On the evening of that day, a dinner was held in honor of the late Samuel P. Langley, secretary of the Smithsonian Institution and previously director of the Allegheny Observatory. The speakers included Dr. John A. Brashear and Dr. J. W. Holland.

We learn from *Nature* that a committee representative of British geologists and friends of Sir Archibald Geikie has presented to the Museum of Practical Geology a marble bust. On March 14, a number of Sir Archibald Geikie's friends assembled in the museum to witness the presentation. Dr. A. Strahan, director of the Geological Survey and Museum, briefly recapitulated the history of the movement. Sir William Garforth unveiled the bust and spoke of Sir Archibald's contributions to science and literature, and then, on behalf of the subscribers, presented the bust to the museum. The Right Hon. J. Herbert Lewis accepted the gift on behalf of the Board of Education; he remarked that it was a source of gratification to the board that the artist commissioned to execute the bust happened to be another of its distinguished servants, Professor E. Lanteri, who had done so much to uphold the standards of the Royal Collge of Art. The Right Hon. Lord Rayleigh then, on behalf of the subscribers, presented to Sir A. Geikie a marble replica of the bust. In acknowledging his appreciation of the gift, Sir Archibald spoke of the powerful effect the Museum of Practical Geology had had upon him in his early student days, and of the great educational value of its collections.

The Royal Society of Edinburgh has elected fellows as follows: Dr. R. J. T. Bell, Dr. F. E. Bradley, Mr. H. Briggs, Mr. C. T. Clough, Dr. E. J. Crombie, Mr. E. H. Cunningham Craig, Dr. A. W. Gibb, the Hon. Lord Guthrie, Professor P. T. Herring, Sir Duncan A. Johnston, Mr. H. Levy, Dr. J. E. Mackenzie, Dr. W. F. P. M'Lintock, Professor R. Muir, Dr. J. Ritchie, Mr. D. Ronald, the Hon. Lord E. T. Salvesen, Mr. D. R. Steuart, Mr. J. Martin White.

Professor Ludwig Becker, a native of Germany, at the desire of the secretary for Scotland, has withdrawn from the chair of astronomy in the University of Glasgow.

DR. WILLIAM E. FAULKNER, of Harvard Medical School, has left for France where he will take charge of the second Harvard medical unit.

AT its meeting held March 8, 1916, the Rumford Committee of the American Academy of Arts and Sciences made the following appropriations: Two hundred and fifty dollars to Louis V. King, of McGill University, in aid of his research on the determination of the molecular constants of gases over the range of temperatures from 25° K. to 1273° K. One hundred and seventy-five dollars in addition to a previous appropriation for the purchase of a comparator to be loaned to Raymond T. Birge, of Syracuse University.

DR. TH. HESSELBERG has become director of the Norwegian Bureau of Meteorology.

HARRY S. SWARTH, formerly of the Field Museum of Chicago, has been appointed curator of birds in the California Museum of Vertebrate Zoology, supported by gift of Miss Annie M. Alexander to the University of California, the budget for this year being $12,000.

DR. STANLEY H. OSBORN has been appointed district health officer by the Massachusetts State Department of Health.

THE board of health of Tuscaloosa, Ala., has appointed A. F. Allen as assistant health officer. Since his graduation from Harvard-Technology School for Health Officers, Mr. Allen has been connected with the health work of Waltham, Mass., and with the epidemiological work in Fitchburg, Mass.

ALFRED W. BOSWORTH, S.B., associate chemist at the New York Agricultural Experiment Station, has been appointed biological chemist for the Boston Floating Hospital.

AT a meeting of the board of government of The National Association of Cotton Manufacturers, held on March 24, Mr. Charles H. Fish was elected acting secretary to fill temporarily the vacancy caused by the death of Dr. Charles J. H. Woodbury.

PROFESSOR R. M. STRONG will conduct the courses and investigations in ornithology at the biological station of the University of Michigan, located at Douglas Lake, Michigan.

COMMISSIONER GEORGE D. PRATT, of the New York Conservation Commission, has secured the services of Mr. Francis Harper, of New York City, to make a detailed study of the fishing waters of Oneida County, New York, as a basis for scientific working plans for fish stocking and protection.

ACCORDING to a cablegram received by the Department of Terrestrial Magnetism the *Carnegie,* under the command of Mr. J. P. Ault, arrived at Port Lyttelton, New Zealand, on April 1, having successfully completed the circumnavigation of the globe between the parallels 55 degrees south and 60 degrees south. Errors in the existing magnetic charts to the extent of 12 to 16 degrees were found.

THE fifteenth Rush Society lecture was given on April 6, at the University of Pennsylvania, by Professor John M. T. Finney, of Johns Hopkins University, his subject being "What Constitutes a Surgeon." This lecture was also the annual address before the Undergraduate Medical Society of the University of Pennsylvania.

DR. R. G. AITKEN, astronomer of Lick Observatory, gave the regular monthly lecture before the Stanford University Faculty Science Association on March 22, 1916, on the subject of "Binary Stars."

MR. GEORGE K. CHERRIE lectured at the American Museum of Natural History on March 17, to the adult blind of Greater New York on "With Colonel Roosevelt on the River of Doubt." Mr. Cherrie was the naturalist detailed by the American Museum to accompany Colonel Roosevelt on the South American trip which resulted in the discovery of the River "Duvida," now named River Roosevelt.

AT the meeting of the Royal Microscopical Society on March 15, Professor J. Arthur Thomson spoke on original factors in evolution, and Sir E. Ray Lankester on the supposed exhibition of purpose and intelligence by the foraminifera.

AT a meeting of the board of government of The National Association of Cotton Manu-

facturers, held on March 24, the following resolution was unanimously adopted:

The Board of Government desires to express its profound sorrow at the death of the secretary of the association, Dr. Charles J. H. Woodbury.

This association, and the cotton industry in general, owes to Dr. Woodbury a debt which is unmeasurable. Devoting himself in early life to the problems of mill construction and fire protection, he has, during all his official connection with the association, of upwards of twenty-five years, been the leader in all movements tending to improve the processes and methods of textile mills. Under the guidance of his trained, scientific mind, the *Transactions* of the association have recorded in the fullest degree the development of the cotton industry in its technical, historical and social aspects; and they stand as a worthy monument to his memory.

Theodore Pergande, the oldest scientific assistant in point of continued service in the Bureau of Entomology of the U. S. Department of Agriculture, died on March 23, in Washington, at the age of seventy-six. He was born in Germany; came to America at the outbreak of the Civil War; served through the war in the northern army, and later became assistant to the late C. V. Riley when the latter was state entomologist of Missouri, coming with him to the Department of Agriculture at Washington in June, 1878. He was a keen observer of the structure and habits of insects, and was especially noted for his work on the Aphididæ.

Professor Harry B. Nixon, who held the chair of mathematics at Gettysburg College, died on March 30.

Léon Labbé, a leading Paris surgeon, member of the French Institute, has died at the age of eighty-four years.

Professor Béla Alexander, director of the radiologic institute at Budapest, died at the age of fifty-seven years on February 10.

Dr. Allan M. Cleghorn, formerly assistant in physiology in the Harvard Medical School, subsequently naturalist for the Algonquin Park in Ontario, and recently captain in the Royal Army Medical Corps, has died in England after a brief illness, at the age of forty-four years.

New York State civil service examinations will be held on May 6, as follows: Physiological chemist, State Department of Health. Salary, $1,800 to $2,500. Applicants should have a thorough knowledge of the principles of organic and physiological chemistry. They must have had at least three years' practical experience in physiological or biological chemistry. Chemist, Public Service Commission, First District. $1,800 to $2,100. Men only. It is essential that candidates shall have had experience in the analysis of asphalt, coal tar, pitches and mixed paints; experience in the analysis of steel, cast iron, cement, dry pigments, water, etc., will be helpful.

According to a cablegram from London to the daily papers arrangements for the fitting out of a relief ship to go in search of Lieutenant Shackleton's Antarctic expedition were being made, though the fate of Shackleton and other members of his party was in doubt. The New Zealand authorities were urged by cable again to attempt wireless communication with the ship *Aurora*, which first reported the Shackleton party in peril. The *Aurora's* wireless message was badly garbled in transmission. Lady Shackleton as well as his explorer friends profess confidence that Lieutenant Shackleton and his men will return alive. They believe Shackleton by this time either has abandoned his attempt to cross the Polar seas from the South American side and is returning to Buenos Ayres, or that he is already safely over the South Pole and will soon join Captain McIntosh and his men at Cape Crozier. Antarctic fowls will supply the party with food if their rations run short, Polar experts declare. Only brief despatches, telling of the disaster to the New Zealand party of the Shackleton expedition, have reached London. According to these despatches, the *Aurora* broke adrift from her moorings last May during a violent blizzard. Captain McIntosh with eight men was ashore at that time establishing a food depot and engaged in scientific explorations. The *Aurora* drifted northward

in the pack ice for ten months, covering a distance of 1,200 miles. Her rudder was snapped off, but after drifting free of the ice field the crew constructed a temporary steering gear. Unless the damage to the *Aurora* was too serious, it is thought possible she may be in condition to return to the relief of the McIntosh party. If a relief ship is fitted out at once it may reach Cape Crozier and escape before winter at the South Pole, coming in June and July, closes the ice barrier again. It is most probable, however, that no relief ship will reach the cape until next December unless the *Aurora* is in shape to return.

THE meetings of the Biochemical Division will be held in connection with the spring meeting of the American Chemical Society at Urbana on Wednesday morning, April 19, and Thursday morning and afternoon, April 20. The sessions on Thursday will be devoted to the presentation and discussion of papers concerning biochemical phases of home economics. This notice is given to correct the erroneous dates published in the earlier announcement.

THE third annual joint meeting of the American Geographical Society and the Association of American Geographers will be held in New York on April 14 and 15. The papers will be delivered at the Hispanic Museum, Broadway and 156th Street, New York City, in the same quadrangle with the American Geographical Society building. The following program has been arranged, to which all interested are invited:

Friday Morning Session (from 10:30 to 12:30)

Leon Dominian, "The Geographic Foundation of Turkey's World Relations."

Mary Verhoeff, "The Kentucky River in Relation to the Kentucky Mountains." Illustrated.

Friday Afternoon Session (from 2:00 to 5:00)

Henry B. Bigelow, "Oceanographic Explorations of the East Coast of the United States." Illustrated.

H. C. Taylor, "Economic Factors Influencing the Geographical Distribution of Crops and Livestock in the United States." Illustrated.

A. Hamilton Rice, "Explorations in the Northwest Amazon Valley." Illustrated.

Saturday Morning Session (from 10:30 to 1:00)

Albert P. Brigham, "Physiographic Provinces of New York."

Harrison W. Smith, "Personal Experiences in the Society Islands and Borneo." Illustrated.

Ernest P. Goodrich, "Some Geographic Problems Incident to the Growth of a Great City—New York." Illustrated.

AT the meeting of the New York Section of the American Chemical Society, on April 7, the subject of "University and Industry" will be discussed from the point of view of the industries by William H. Nichols. Discussion will follow by Marston T. Bogert, Columbia University; Eleon H. Hooker, Hooker Electrochemical Company; Phoebus A. Levene, The Rockefeller Institute for Medical Research, and Benjamin L. Murray, Merck & Company.

THE meeting of the Astronomical Society of the Pacific was held on March 25, at the Students Observatory, Berkeley, when the following program was presented: "Comet A 1916" (Neujmin), by Miss Jessica M. Young. "The Riefler Clock," by Professor R. T. Crawford. "On the Universality of the Law of Gravitation," by Professor A. O. Leuschner.

THE Washington Academy of Sciences announces a series of illustrated lectures on nutrition, open to the public, to be given on Friday afternoons during April, 1916, at 4:45 o'clock, in the auditorium of the New National Museum. The lectures and the subjects of their addresses are as follows:

April 7. Dr. Eugene F. DuBois, medical director Russell Sage Institute of Pathology, New York: "The Basal Food Requirement of Man."

April 14. Dr. Graham Lusk, professor of physiology, Cornell University Medical College: "Nutrition and Food Economics."

April 21. Dr. E. B. Forbes, chief, department of nutrition, Ohio Agricultural Experiment Station: "Investigations on the Mineral Metabolism of Animals."

April 28. Dr. Carl Voegtlin, U. S. Public Health Service, Washington: "The Relation of the Vitamines to Nutrition in Health and Disease."

A COURSE of six lectures on military administration, medicine and surgery is being given at the College of Physicians and Surgeons, Columbia University, on Tuesdays, at 5 P.M., beginning March 28. The lectures, which are

open to the general medical public as well as to students at the college, are as follows: March 28, Organization, Equipment and Training of Armies, by Lieutenant Colonel William S. Terriberry, Medical Corps, N. G. N. Y.; April 4, Organization of the Medical Department, and Its Service in Campaign, by Major Joseph H. Ford, Medical Corps, U. S. A.; April 11, Wounds in War, their Complications and Treatment, by Major Joseph H. Ford, Medical Corps, U. S. A.; April 18, The Personal Hygiene of the Soldier, by Major Sanford H. Wadhams, Medical Corps, U. S. A.; April 25, Camp Sanitation, by Captain Philip W. Huntington, Medical Corps, U. S. A.; May 2, Preventable Diseases in War, by Captain Philip W. Huntington, Medical Corps, U. S. A.

All medical classes at the university were omitted on Thursday, April 6. The day, which is known as "U. M. A. Day," and which belongs to the Undergraduate Medical Association, was devoted to the presentation of papers and exhibits of original research work by the undergraduates and to addresses by members of the medical profession. "U. M. A. Day" was founded in the fall of 1907 by Dr. John G. Clark for the purpose of encouraging among undergraduates original research along scientific lines.

At a hearing on the Wheeler bill before the New Lork legislature, Dr. Max G. Schlapp stated according to the *Journal* of the American Medical Association, that a donor who did not wish his name divulged had offered $500,000 toward a psychopathic institution provided the Wheeler bill was passed by the legislature. This bill would create a state clearing house for the mentally deficient and would create a commission of seven with an executive manager to supervise the work of examining and diagnosing the cases of the mentally deficient and to investigate the causes of mental deficiency. No one opposed the bill.

The Department of Experimental Breeding at the University of Wisconsin has recently occupied its new barn, constructed for the accommodation of the experimental herd, and fitted out with the most modern barn equipment. An attempt is being made by means of crossbreeding to obtain data on the inheritance of dairy and beef characteristics. The herd at present consists of nearly a dozen crossbred cattle of Jersey-Aberdeen Angus parentage, and one calf of the second generation.

On the petition of Dr. J. Allen McLaughlin, state health commissioner, a bill has been introduced before the Massachusetts General Court which aims to prevent the sale or delivery of milk in any city or town without a permit from the local board of health after inspection of the facilities for producing and handling this food. It provides that the permit may contain reasonable conditions for the protection of the public health and may be revoked for failure to comply therewith. The bill has been referred by the Senate to the committee on agriculture and public health.

UNIVERSITY AND EDUCATIONAL NEWS

Harvard University has received a bequest of $51,500 from the estate of J. Arthur Beebe, and one of $50,000, came from the estate of Mrs. William F. Matchett, the income of both to be used for general purposes.

Dr. George E. Vincent, president of the University of Minnesota, delivered the Annual Charter Day address in the open-air Greek Theater of the University of California on March 23. That afternoon the cornerstone was laid of the $730,000 white granite classroom building to be known, in honor of President Wheeler, as Benjamin Ide Wheeler Hall.

Mr. F. W. Bradley, of San Francisco, has given $5,000 to the University of California for the purchase of additions to the geological and mining-arts collections of the university. A large number of exhibitors at the Panama-Pacific International Exposition have also contributed to the university's collections in these fields, among these donors being Japan, Norway, Sweden, Bolivia, United States Bureau of Mines, United States Geological Survey, the Transvaal Chamber of Mines,

Australia, Missouri, New York, California, Idaho, Anaconda Copper Company, the Utah Coal Operators' Association, the Tourmaline King Mine, the Union Oil Company, the Mascot Copper Company, the After-thought Mining Company, the Noble Electric Steel Company, the Bunker Hill and Sullivan Company, the Hockensmith Wheel and Mine Car Company, the Concordia Safety Lamp Company, the Chicago Pneumatic Tool Company and Mrs. Phoebe A. Hearst.

UPON the occasion of moving into its new quarters, the department of chemistry of the University of Illinois has issued a bulletin containing complete information of the courses given. The bulletin contains also a history of the department and pictures of the different buildings it has occupied during its growth. It contains also a list of the students registered in the chemistry courses and all alumni of the department. This bulletin will be of service on the occasion of the meeting of the American Chemical Society during the week of April 17 to 21.

A STATUTE which makes a certain amount of research a necessary qualification for the honor school of chemistry at Oxford, has been approved in congregation. The professor of chemistry, Mr. W. H. Perkin, said the main object of the scheme was to secure that every undergraduate who desired a class in chemistry must have had a year's training in the methods of research. As a result they would be able to engage in independent research and would be of more value to the country whether they ultimately adopted a teaching or an industrial career.

THE faculty of the College of Physicians and Surgeons, of Columbia University, have unanimously voted in favor of the establishment of a dental department, to be connected with the medical school. A committee of prominent dentists of the city have presented plans to the medical faculty which have been approved. The course is to be four years.

AT Yale University, Dr. Rhoda Erdmann has been appointed lecturer in biology, for the year 1916-17, on the Sarah Berliner Foundation.

DR. FRANK BILLINGS, of Chicago, has been appointed visiting lecturer on medicine at Harvard University.

AT the University of Cambridge, Mr. S. W. Cole, of Trinity College, has been appointed university lecturer in medical chemistry, and Mr. C. S. Gibson, of Sidney Sussex College, assistant to the professor of chemistry.

DISCUSSION AND CORRESPONDENCE

SEMINARY COURSES IN THE HISTORY OF SCIENCE

THE question of giving more attention to the history of science in the training of scientific men, which has already been raised in recent issues of SCIENCE, is one which should not be allowed to pass without some tangible result in the form of new courses within that little exploited field. As one who at biennial periods has conducted a seminary in the history of geology, I may perhaps be permitted to draw attention to some of the special benefits, to both teacher and pupils, which are likely to accrue from such courses.

Most important, perhaps, of the results obtained are the following: (1) A wider knowledge of the entire field of the science together with the intimate interrelations of its several parts; (2) a comprehension of what may be termed the psychology of hypothesis-making and its dependence upon the local environment of the maker, upon pure analogy, upon the scientific vogue of the period, or upon the dominating influence of leading minds; (3) a greater caution in setting up new theories upon small evidence through learning of the number and the variety of earlier theories and the relatively small number of them which have survived the test of time; (4) the valuable and often wholly unexpected side-lights which are thrown upon problems within a special field by discoveries made in other fields which were perhaps thought to be but little related.

Of these benefits I am inclined to think that much the most valuable is (2)—the realization that the scientists, as well of to-day as of yesterday, are not essentially different from their

brother mortals in the avocations, but are subject to much the same weaknesses of mental bias growing out of their early training, their religious or other beliefs, the effects of dramatic demonstrations, or the emotional effects produced by oratory and clever sophistry, as contrasted with sound reasoning divorced from such considerations.

In this connection I should like to cite a few illustrations. Who will venture to measure the part played by the unique rings of the planet Saturn in determining the form of the nebular hypothesis of Laplace, until lately accepted doctrine though now shown to be untenable? Is it not easy to see that the doctrine of a solid "crust" above a liquid earth interior—a part of the nebular hypothesis—was set up and readily accepted because the theorist who devised it inhabited a region where water congeals during the winter season and floats upon its liquid equivalent—the analogy was carried over to the substance whose relative densities in solid and liquid form were not known, from analogy with a well-known substance. Only recently has it been definitely learned that congealed rock is heavier than its liquefied form. Again, the "centrum," or explosion, theory of earthquakes, which till recently held the center of the stage in seismology, can be traced to the fact that its founder was a builder of cannon, and acquired such prestige during the Crimean War through his knowledge of ballistics that he received unusual opportunities to study a famous earthquake under the Aegis of the powerful Royal Society of London. A secondary factor in the ready acceptance of his theory by physicists particularly, was his application of the brilliant studies of Huyghens on wave propagation. Examples might easily be multiplied in order to illustrate the controlling influence of fortuitous circumstances or of striking, as opposed to solid, arguments in determining the character of the body of accepted doctrine within a science. Each worker who has given attention to the subject, will surely have encountered similar illustrations within his own field, and I feel sure that if courses in the history of science were to be more generally undertaken, they would hardly be abandoned through any lack of interest.

Wm. H. Hobbs

University of Michigan,
March 7, 1916

DEMOCRATIC ORGANIZATION IN A COLLEGE DEPARTMENT

To the Editor of Science: The work of the Entomological Division of the Minnesota Agricultural College and Station has increased to such an extent in the past four years, that, on November 1, 1915, a reorganization of the division took effect. Two other divisions were placed on the same basis. The new organization is as follows:

The name of the division is changed to that of Economic Zoology. It is divided into four sections: (*A*) Economic Vertebrate Zoology, Professor F. L. Washburn in charge, who, as state entomologist, also conducts nursery inspection work and has charge of work with mill and warehouse insects and with Minnesota Hymenoptera. Mr. Washburn retains his title of professor of entomology in the University of Minnesota. (*B*) Spraying and Tree Insects, Associate-Professor A. G. Ruggles in charge. (*C*) Field Crop Pests and Parasites, Assistant Professor C. W. Howard in charge. (*D*) Greenhouse and Truck Crop Insects, Assistant Professor William Moore in charge.

The administration of the division lies in the hands of a committee composed of the heads of sections. The chairman of the committee (an executive position) is appointed annually by the dean of the college, with the approval of the president of the university and of the board of regents. Professor F. L. Washburn was appointed chairman for the present year. The position of chairman carries with it that of entomologist to the experiment station and a state law provides that the station entomologist shall be state entomologist.

This organization is rather a remarkable step in the direction of greater democracy in the management of a university department and may interest entomologists and other science workers in universities.

F. L. Washburn

University of Minnesota

SCIENTIFIC BOOKS

A Text-book of Geology, in two parts. Part I., *Physical Geology*. By L. V. Pirsson. Part II., *Historical Geology*. By Charles Schuchert. John Wiley & Sons. 1915. Separately, Part I., $2.25; Part II., $2.75. Parts I. and II. bound in one volume, $4.00.

It is most fitting that this book, issued by two members of the Yale University Geological Department, should be "Dedicated to the memory of James Dwight Dana, Explorer, Geologist, Naturalist, Professor in Yale University"; to the man who first made this department so famous.

This book of 1,060 pages, with 522 illustrations and 40 plates, is divided into two parts. Part I., by Professor Pirsson, consists of 404 pages, and deals with physical geology. Part II., by Professor Schuchert, discusses historical geology and has 647 pages. It is an excellent plan to issue the parts separately, as well as combined. They are similar in size and binding to Bowman's "Forest Physiography" and Ries & Watson's "Engineering Geology." The binding is well done, the type is good, the illustrations are well produced and there are practically no typographic errors. The publishers and authors are to be congratulated upon this production.

Part I. is an excellent presentation of the fundamental facts and principles of physical geology. The subject is treated under two main captions, namely, Dynamical Geology and Structural Geology. In view of the statement made in the preface, that the author has attempted to produce a text-book which should have "a balance more even in the subject-matter composing it, than is to be found in available texts," the reader may question the space allotment assigned to the different chapters, as follows: Introduction, 5 pp.; General Considerations and Work of the Atmosphere, 22 pp.; Rain and Running Water, 42 pp.; Lakes and Interior Drainage, 10 pp.; The Ocean and Its Work, 27 pp.; Ice as a Geological Agency, 34 pp.; Underground Water, 17 pp.; The Geological Work of Organic Life, 23 pp. (is there such a thing as inorganic life?); Igneous Agencies, and Volcanoes and Hot Springs, 38 pp.; Movements of the Earth's Outer Shell, 23 pp. These chapters belong under Dynamical Geology. The structural side is treated in the remaining chapters: General Structure and Properties of the Earth, 11 pp.; Sedimentary Rocks, 39 pp.; Igneous Rocks, 21 pp.; Metamorphic Rocks, 18 pp.; Fractures and Faulting of Rocks, 17 pp.; Mountain Ranges, 31 pp.; and, Ore Deposits, 24 pp. Unless the reviewer is mistaken, he understands that the "balance" was obtained by averaging the space given to each subject by authors of older text-books of general geology.

In putting dynamical geology before structural geology the writer leads his readers from the known to the unknown. In many respects this is far more satisfactory for beginner's classes than the philosophical order according to which the masses operated upon by geologic forces should be described before considering the action of these forces.

An elementary text-book should excel, first and foremost, in the clearness of its exposition and in the choice of its illustrations. In both respects, "Physical Geology" is deserving of high praise. Almost without exception the language is lucid and concise, although we do read of "pouring dry dune sand from San Francisco" (p. 15). The half-tones are well chosen and excellently printed. With reference to the line diagrams perhaps a word of criticism may be said. Fig. 13 is incorrectly drawn; Figs. 74, 225, 227, 230 and 231 are misleading; and the perspective is faulty in Figs. 129 and 149. More uniformity might have been attained had the block diagrams been constructed either in perspective or in isometric projection, or, preferably, in cabinet projection. Thus, the blocks shown in Figs. 271, 272 and 273 might have been drawn in similar positions instead of being tilted at various angles.

There are a few places in the text where statements are misleading or incorrect. On p. 11 we find that, in a classification of work performed by the atmosphere, the chemical

destructive processes are designated *weathering*, as if there were no mechanical weathering, but this oversight is later corrected (p. 19) by the assertion that both mechanical and chemical processes fall under the head of weathering. Talus is described as having the coarser fragments above and the finer particles below (p. 22). As a matter of fact, true talus deposits, as distinguished from alluvial cones, are fine above and coarse below. "Bedrock" and "country rock" are defined as synonymous (p. 19). "Bedrock" should refer to solid rock in situ as distinguished from the unconsolidated superficial mantle rock. "Country rock" should be applied only to an older rock or rock complex, which has been invaded by younger veins or eruptive bodies. The distinction between base level and grade does not seem to be clearly brought out (p. 66). A *base level* is a *level* which controls the downward cutting of one or more streams. The control is such that each stream can reduce the inclination of its channel to a certain slope below which further downward cutting is impossible. This *slope* is *grade*. Only the lower end of such a graded stream can actually reach base level.

After all is said, these imperfections are of relatively minor importance, and they do not seriously detract from the usefulness of the volume *as a text-book*. If "Physical Geology" is also intended for a reference book—and such every elementary text-book should be with regard to the matter which it treats—its abbreviated table of contents and its incomplete index are to be deplored. In the table of contents should appear all the center and side headings employed in the text. Instead, merely chapter headings are given. Nothing described or referred to in the text should be omitted from the index. Yet coal, outwash plain, bedrock, country rock, etc., are not to be found. It is to be hoped that in a second edition the writer will correct these two grave defects.

Part II.—Professor Schuchert has given us a very readable, up-to-date book from the first chapter on "Matter and Organisms" to the last on "Earth History in Retrospect." It is unique in its method of treatment but with a uniqueness that appeals. The book consists of a series of lectures upon the principal events, physical and biologic, in the history of the earth. Each lecture or chapter deals with a single subject.

The ground is prepared for a clearer understanding upon the part of the reader by the first seven chapters, "Matter and Organisms"; "Evolution, the Constant Change of Living Things"; "Fossils, the Geologist's Time Markers"; "The Geological Time-table"; "The Lands and Their Life"; "Oceans, Their Deposits and Their Life"; "Seas, Their Nature and Deposits." There follow two chapters on the solar system, "Evolution of the Stars and the Solar System" and "Origin of the Solar System under the Planetesimal Hypothesis," the latter by Professor Barrell of Yale. In these chapters the planetesimal hypothesis of Chamberlin and Moulton is accepted as coordinating more known facts of the entire solar system than any other thus far propounded. The next chapter, "Primordial Geologic Time" applies this hypothesis more directly to the earth and its known rocks.

With the succeeding chapter begins the discussion of the history of the sedimentary rocks of the earth and their included organic remains, a consideration of the somewhat unstable continents and the ever encroaching oceans. The author, though in his research work advocating the uniform "ic" endings for the period names, very wisely in this undergraduate text-book uses the older endings, the endings used in the publications of the national surveys of the United States and Canada, of nearly all state surveys and by the majority of other geologists. There are three chapters devoted to the pre-Cambrian, "The Archeozoic Era" and "The Early and Late Proterozoic Sub-eras." Next is one on "The Paleozoic Era," in general, in which is briefly given the larger features of the North American continent during this era, especially a consideration of the more permanent land and water bodies. This includes a map (p. 577) giving the larger positive, or predominantly

rising areas, and the negative elements, the dominantly sinking areas, of the North American continent. The larger positive elements for the world are given in maps on pp. 462 and 463.

In the fifteen chapters devoted to the Paleozoic era, seven to the Mesozoic and four to the Cenozoic, the author reveals his familiarity with the geologic history of North America and its life, and here too he departs frequently from the older methods of presentation. At the first important occurrence of a group of organisms he discusses its zoology, evolution and in general its geologic occurrences, alluding but briefly to them later under the separate periods. For example, trilobites, brachiopods and all the mollusk classes are discussed between the chapters on the Cambrian and Ordovician. Fishes are given a chapter to themselves just before the Devonian discussion, and here are considered all subclasses, even though the dominant modern type of fish, the Teleostei, do not make their appearance until the Jurassic. There might be a difference of opinion as to the advisability of grouping the cœlenterates and echinoderms under the old name of "animals with a radial symmetry" and of discussing all classes of these together directly after the Ordovician.

After the general discussion of the Paleozoic one chapter is devoted to the Cambrian, one to "Trilobites" and one to "Shelled Animals." The Ordovician consumes one chapter, "Animals with a Radial Symmetry" and the "Silurian" each one. Then in succession are discussed "Fishes and the Ancestors of Vertebrates," "Devonian Time," "The Old Red," "Carboniferous of Older Geologists and the Mississippian Period," "Pennsylvanian-Permian Periods," "Rise of the Land Floras," a chapter on "Coal," and one on "The Earliest Land Vertebrates." While the discussion of coal is the best that has thus far appeared in a text-book on general geology, a brief consideration of the results of E. C. Jeffrey's work on the origin of coal and a view of one of his remarkable thin sections of coal would have added much to the completeness of the discussion.

The Mesozoic opens with a consideration of "The Triassic Period," which is followed by a chapter by Professor Lull on "Dinosaurs." Then follow in order "The Jurassic"; "Ammonites and Belemnites," a very brief chapter; "The Comanchian"; "Chalk"; "The Cretaceous Period and the Laramide Revolution." The four chapters of the Cenozoic are: "The Dawn of the Recent in Cenozoic Time"; "Evolution of Mammals and the Rise of Mentality" (including a discussion in greater detail of the evolution of the camels, horses and elephants); "Pleistocene" and "Man's Place in Nature," this last a 17-page discussion of man, biologic and geologic. The lectures close with a most concise and helpful fourteen-page summary chapter—"Earth History in Retrospect."

In the discussion of a period the author begins with a brief presentation of its occurrence in its earliest known areas, usually Europe. This is done by an account of the advances and retreats of the oceans and the mountain upheavals. Then follows a consideration of North America in greater detail, giving stratigraphic thicknesses and the paleogeography of the principal portions of the continent. This is followed by a synopsis of the life. The chapter is usually closed by a brief discussion of the climate and the economic products of sedimentary origin. The many figures illustrating the invertebrate life are commendably simplified for beginners by having their technical names banished to an appendix. Very seldom is the distribution of deposits throughout the world noted. We would thus not look to this book to find if Australia has Silurian deposits or China those of Mississippian age.

A pleasing innovation is the inclusion of the portraits of famous geologists. William Smith is given in the discussion of the Jurassic, the study of which in England led him to the discovery of the principles underlying historical geology. Lyell is given in the Cenozoic, Suess in the Cretaceous, Murchison in the Silurian and Sedgwick in the Ordovician. Of the North American workers Logan looks upon us from the pages of the Archeozoic, Hall

from the general Paleozoic discussion, William Dawson from the Devonian, Dana is given under the consideration of the permanency of continents and ocean basins, while Darwin, Wallace, Huxley and Lamarck are seen among the statements of evolution.

As was to be expected from one of the world's foremost paleogeographers not the least of the many excellent features of the book are the discussions of the past geography of the earth and the many original maps to illustrate it. There are usually several paleographic maps of North America for each period.

The book is so filled with interesting matter that it is difficult to pick out topics for special remark. It is, however, noteworthy that the text-book issuing from the university which saw the birth of Dana's "Manual of Geology" should advocate, though in a less rigid form than did Dana, the permanency of the oceanic and continental areas, the theory propounded by him. "Since the beginning of Paleozoic times the oceanic basins and the continental masses have been more or less permanent." This permanency is more flexible in the continental masses whose dominant movement is upward, for portions of these are at times invaded by the ocean or have parts of their masses faulted off into the oceanic basins.

The author's discussion of the early life of this globe must also be mentioned. "At the very base of the geologic record, in the Archeozoic," he says, "the rocks testify to a world with about the same physical environment as that of subsequent time." The presence of life in the marine waters at this time is shown by the carbonaceous shales and the large amount of graphite. No fossils are known. It is assumed that the Archeozoic was the "age of unicellular life," both plant and animal. By the close of this long era it is postulated that small multicellular plants and animals had also been evolved. Among the latter were morulæ, gastrulæ and planulæ, known at present as early embryonic stages in the development of existing animals. From the Proterozoic a small number of fossil species are known. These are "an abundance of marine algæ, some radiolarians and tubes and burrows made by annelids." The presence of annelids implies the existence of the more lowly organized sponges, cœlenterates and worms. So likewise the presence here of such other invertebrate phyla as the echinoderms, molluscoids, mollusks and arthropods is indicated by the highly evolved state of all these phyla at the opening of the Paleozoic. The author thus rejects Walcott's theory that the Proterozoic fossils thus far known are most probably non-marine and that in the at present unknown Proterozoic oceans developed the life which made so sudden an appearance in the lowest Paleozoic sediments. He agrees with Daly and Lane that the early marine waters had a different chemical content but objects that this alone could cause animals to so largely secrete chitinous, instead of calcareous skeletons, while the plant organisms, especially algæ, at the same time formed great thicknesses of limestone through their calcareous secretions.

As to the evolution of insects "it is thought that out of some Silurian or Devonian trilobite that habituated itself to the land-waters and became amphibious was derived the stem stock of insects."

That modern necessity, a good working index, is here well met. Only a few examples of oversight were noted. One was the failure to refer to the discussions of pre-Cambrian and late Paleozoic occurrences under the word glaciation. All references are to the Pleistocene.

An excellent generalization of the U. S. Geologic map, 14 by 17 inches, is inserted immediately before the index. It is thus easily accessible for reference without interfering with the usefulness of the index. It would be of still greater aid to the student if it had a blank base so that when unfolded the entire map would be visible though the back were closed. This would enable the map to be constantly before the student, no matter what part of the book he was reading. It is unfortunate that in the legend of this map the author uses the "ic" endings to the period names without

an explanation and substitutes for Paleogene used throughout the book for the lower Tertiary the term Eogenic.

Hervey W. Shimer,
Frederic H. Lahee

Massachusetts Institute of Technology

Modes of Research in Genetics. By Raymond Pearl, Biologist of the Maine Agricultural Experiment Station. The Macmillan Company. Pp. 182. Price $1.25.

In this book Professor Pearl has paused in the midst of his prolific and fruitful researches to put together in logical sequence around the central theme of methodology in genetics the substance of several of his recent papers and addresses.

There has been need enough for such a clear-cut analysis of the possibilities and limitations of the various methods now being utilized by workers in the expanding field of genetics and the author has performed this service most acceptably.

It is particularly gratifying to have a sane non-controversial evaluation of the much abused biometric method by one who is a past-master in biometry and is at the same time a biologist of notable attainment. It must be confessed that biometry of late years has rather needed a champion since non-mathematical biologists while admiring the magic of the biometrician, are often haunted with serious doubts about the value of the conclusions sometimes reached by this mode of investigation.

Although biometrics receives the most extended consideration of any method there is a comprehensive analysis of three other modes of research, namely, the Mendelian, the cytological and the embryological.

The next to the last, and the longest, chapter diverges into a somewhat technical treatment of the problem of inbreeding. Here the average lay reader is likely to ride through a tunnel with only intermittent glimpses of the light, but he is sure to emerge into broad daylight in the final chapter, which is upon "Genetics and Breeding," and feel well repaid for his journey. For any one engaged, or even interested, in genetic research Dr. Pearl's book will prove a most welcome and illuminating volume.

It is obvious that "Table III." on page 111 should read Table I.

H. E. Walter

An Introduction to the Study of Variable Stars. By Caroline E. Furness, Ph.D. Boston, Houghton Mifflin Company. 1915. Pp. 327. $1.75 net.

It is rather remarkable that no comprehensive work on variable stars had previously appeared in any language, though Hagen's extensive treatise, "Die veränderlichen Sterne," of which the first two parts have already been published, would soon have been completed had the war not delayed it. It is very timely in view of the great expansion in the past few years, not only in the observations of variable stars, but more especially in the deductions from their phenomena. Cosmic theories have drawn heavily on these phenomena, and seem likely to gain still more from further study.

Following the introductory chapter the work falls naturally into four divisions.

1. The equipment of the observer; maps, charts, catalogues: Chapters II. to V.

2. Photometry of variable stars; visual, photographic, photo-electric: Chapters VI. to VIII.

3. Reduction of the observations; light-scale, light-curves, elements and predictions: Chapters IX. to XI.

4. Deductions from these data; eclipsing and long-period variables, statistics, observing hints, tables: Chapters XII. to XV.

That the book is written from the standpoint of the teacher is well evidenced by the care taken to explain the fundamental ideas of each chapter. For example, the elements of spectrum analysis and radial velocity are given in considerable detail, a precaution very necessary to clarify the hazy ideas held by young students of spectroscopy. The principles underlying the photometric instruments are set forth in detail, especially the photo-electric appliances which have so recently entered the field of stellar photometry. A human interest is added by brief biographical sketches of some of the older great astron-

omers whose work laid the foundations for modern progress.

The amateur will thus find not only clear and complete directions for work, but the basic principles which enable him to understand the significance of his results. The professional astronomer will also find the book useful on account of its convenient collection of data for which he had been obliged previously to search through periodicals.

The specialist in astrophysics will naturally find some points capable of clearer statement, and some minor errors such as are apt to creep into first editions. For example, the Zöllner photometer is described on page 118 as used with the historic petroleum lamp, rather than with the modern incandescent lamp. The lack of wave-lengths on the margins of the engravings of spectra is puzzling to one not thoroughly familiar with them, especially as Plate XI. is printed with the violet end to the right, instead of the usual direction. Chapter XII., entitled "Eclipsing Binaries," includes also the "Cepheid Type," though it is not claimed that their changes can be explained by eclipses. On page 229 is the statement that "It was only with the selenium cell that it was possible to determine a change so small as 0.06 magnitude," though as a fact, the extra-focal photographs are capable of determining such changes. The use of *mg.* as an abbreviation for magnitude, is unfortunate, as it usually stands for milligram. Compare the statement in the *Scientific American* that the planet Saturn is 16 inches in diameter, due to the use of the double stroke as a sign of both inches and seconds of arc. This is not the place to give a list of typographical errors, but the statement at the top of page 102, that if star *A* is twice as bright as star *B*, the difference in magnitude is 0.44, might mislead. In the examples of the use of Pogson's rule, in Chapter V., the omission of the problem of finding the combined magnitude of two or more stars, is worth mentioning. In the historical part, the failure to give Mrs. Fleming credit for her part in the creation of the Harvard classification of stellar spectra; also the failure to credit the astronomer royal, Christie, for the "square-root" formula for the reduction of the diameters of stellar images on photographs, to magnitudes, are minor points which might be corrected.

In spite of these minor criticisms the book is a worthy contribution to the series celebrating the semi-centennial of Vassar College.

J. A. PARKHURST

YERKES OBSERVATORY,
WILLIAMS BAY, WIS.

THE VITAL EQUILIBRIUM

FOLLOWING the suggestion of Nernst[1] that varying degrees of permeability of the plasma membrane might be due to a selective solubility of certain of its components, Overton established his lipoid theory. The most serious objection to Overton's theory is that, whereas it accounts most satisfactorily for the permeability of the cell for substances which normally play no part in the cell metabolism, it entirely fails to explain the penetration of sugars, salts and amino-acids, which must constitute an essential part of the cell income. Loeb[2] long ago emphasized the importance of the state of aggregation of the surface colloids as one factor influencing the conditions of permeability. This suggestion was made in connection with his experiments upon the effects of pure solutions of NaCl and combinations of NaCl and polyvalent ions on the eggs of *Fundulus*. Subsequent experiments by Loeb, Höber, Lillie and a host of others, have established beyond a doubt the existence of a physical-chemical relation between the state of aggregation of the cell colloids and the permeability of the cell. A precise and universal statement of the exact nature of this relation has never been made. In the following paper we shall attempt an analysis of the conditions determining the viscosity of cell surfaces and their importance; (1) in producing changes in permeability and (2) in "antagonisms." It appears that the metabolic

1 Nernst, W., '90, *Zeitschr. f. physikal. Chem.*, 6, 37.

2 Loeb, J., '01, *Pflügers Arch.*, 88, 68; '02, *Amer. Jour. of Physiol.*, 6, 411.

activities of cells, in so far as they involve an interchange of material through the surface layer, depends upon the shifting of a *surface-solution equilibrium*. Since an interchange of material eventually becomes essential for the continuation of any living system, we have called this solution equilibrium the "Vital Equilibrium."

If we examine a series of two-phase systems beginning with a coarse suspension and extending through fine suspensions, colloidal suspensions, colloidal solutions, hydrophilous colloidal the "molecular disperse" systems of Ostwald and ionically disperse systems such as dilute solutions of electrolytes like NaCl, we observe two striking changes: first, an increased subdivision of the disperse phase and, second, an increased intimacy of relation between disperse phase and solvent, a necessary result of the enormously developed surface in the former.[3] We find, furthermore, that in any of these systems there always exists an equilibrium between disperse phase and solvent. The opposing forces are in the direction of an increased aggregation and dispersion, respectively; we may therefore speak of an aggregation equilibrium. This equilibrium is shifted by the addition of solutions of any substance, organic or inorganic, by heat, ultraviolet light, etc. For example, if we add $CaCl_2$ to the negative suspension colloid As_2S_3, a precipitation occurs, *i. e.*, there is an increased aggregation of the disperse phase. Reciprocally, small quantities of 0.1 N $CaCl_2$ will clear an opaque colloidal solution of egg-white. There is an increased dispersion and the system becomes more like a true solution. Now the limits of the above series are total insolubility and complete solubility. Any change in the direction of increased dispersion means a change in the direction of a true solution, *i. e.*, an increased solubility. No sharp limits occur between true solutions and colloidal solutions. A solution of cane sugar, for example, though a molecular disperse system, certainly represents a lesser degree of dispersion than any solution of an electrolyte. Again, when two salt solutions having a common ion are combined, there appears the familiar phenomenon of association or decreased dispersion, an equilibrium shift in the direction of greater aggregation, in this case from ionic to molecular dispersion. We may therefore legitimately dispense with the term "aggregation equilibrium" and, even though we are dealing with colloidal systems, substitute the more familiar "solution equilibrium."

The hydrophilous colloids which are of particular interest to physiologists are peculiarly susceptible to slight changes in hydrogen ion concentration. Here the changes in aggregation are reversible to a far greater degree than in the colloids lower in the scale. The limits of reversibility of the solution equilibrium may be said to include a far greater range of aggregation states than in the colloids of the lower classes.

An examination of the experimental data[4] shows that for a number of different hydrophilous colloids the following anion order of dispersion obtains:

$$SO_4 < \text{Tartrate} < \text{Citrate} < \text{Acetate} < Cl < ClO_3 < NO_3 < Br < I < SCN.$$

The most indifferent region lies between acetate and chloride; SO_4 has the greatest tendency towards aggregation, while SCN produces maximum dispersion.[5] In many cases, especially in precipitation experiments, the addition of the electrolyte may have no visible effect upon the colloid. When this occurs the changed equilibrium may be detected by a vis-

[3] Höber, R., '14, *Physikal. Chemie d. Zelle u. d. Gewebe*. 4 Aufl., Kap. 7, p. 305 ff.

[4] Hofmeister, F., '91, *Arch. exper. Pathol. u. Pharmakol.*, 28, 210; Höber, R., '07, *Hofmeisters Beitr.*, 11, 35; Porges u. Neubauer, '07, *Biochem. Zeitschr.*, 7, 152; Hardy, '05, *Jour. of Physiol.*, 33, 251.

[5] By a sufficient increase in the hydrogen ion concentration the anion order may be *completely inverted*. Thus the effect of an alkali salt upon the state of aggregation of any hydrophilous colloid depends directly upon the hydrogen ion concentration. Posternak, '01, *Ann. Inst. Pasteur*, 15, 85; Pauli, W., '03, *Hofmeisters Beitr.*, 5, 27; Höber, R., '07, *ibid.*, 11, 35.

cosity determination, one of the most accessible methods for tracing changes in the state of colloidal aggregation.

The viscosity of colloids or its reciprocal, fluidity, shows peculiar variations with different degrees of dispersion. When the dispersion is greatest, *i. e.,* when the disperse phase is in "solution," we find that the fluidity is also at a maximum. An increased aggregation means a decreased fluidity which, however, continues only to the point at which the disperse phase begins to separate out from the dispersion medium as a suspension colloid or suspension. When this point is attained, the fluidity is suddenly reversed and approaches more and more that of the pure dispersion medium. Now whether the precipitation of the disperse phase is brought about by the action of electrolytes or, for example, by elevated temperature (heat coagulation) the physical-chemical effect upon the fluidity is the same (Fig. 1, *B*).

Since all substances have an influence one way or the other upon the solution equilibrium of a colloidal system, we may, theoretically, divide them into two groups; (1) those favoring solubility of the disperse phase (increased dispersion, increased fluidity) and (2) those favoring insolubility (aggregation, precipitation, coagulation, initial increased viscosity).

Turning now to the conditions of the colloids especially at the surfaces of cells, we find, in some cases, sharply differentiated membranes. In many animal cells such membranes are not demonstrable, but for our present discussion this is of little moment, since we are concerned with a colloidal boundary which must exist at the surface of every cell. In experimental studies upon single cells as, for example, animal eggs, variations in the constitution of the environmental medium produce profound changes in the cell. Whatever changes may occur within the cell as a result of such variations, it is certain that these changes are secondary to an initial or primary effect at the cell surface. Liquefying agents are believed to produce an increase in cell permeability.[6] *Arbacia* eggs, for example, when treated with solutions of sodium or potassium thiocyanate, begin to lose their pigment after two or three minutes. This is to be regarded as an expression of an increase in the normal permeability of the cell surface.

It has been shown for a number of physiological objects[7] that the deleterious action (liquefying action) of neutral alkalin salts decreases from SCN to Cl in an order corresponding satisfactorily with the Hofmeister series. In these experiments, when the solutions of the salts are brought into contact with the cell surface, the degree of dispersion of the surface colloids must be increased. The dispersion is greatest in solutions of thiocyanates and least in chlorides. A physico-chemical expression of this increased dispersion is the increase in the fluidity of the cell surface. Now, since the speed of diffusion of ions and molecules through any fluid medium depends upon the viscosity of that medium,[8] it is clear that an increased fluidity of the cell surface involves a facilitation of diffusion of soluble substances from either side of the cell surface. In other words, by a liquefying action at the surface, the permeability of the cell is increased and diffusion in both directions across the surface is facilitated.

Since there is this very definite correlation between liquefaction (dispersion) and increased permeability, it is obvious that, in the normal condition of the cell, we must have a greater aggregation of the surface colloids than during liquefaction. Bearing in mind the fact that pure solutions of all substances affect the solution equilibrium of colloids one way or the other, we should expect, *a priori,* to find certain agents producing an increased aggregation of the surface colloids of the cell; we should expect to find true solutions of

6 Lillie, R. S., '13, *Jour. of Morphol.,* 22, 695.

7 Schwarz, C., *Pflügers Arch.,* 117, 161; Lillie, R. S., '10, *Amer. Jour. of Physiol.,* 26, 106; Spaeth, R. A., '13, *Jour. of Exper. Zool.,* 15, 527.

8 In the case of water-swollen gels, the speed of diffusion of crystalloids is approximately the same as in pure water, but it diminishes rapidly when the water content falls below a certain value. Bechhold u. Ziegler, '06, *Zeitschr. f. physik. Chemie,* 56, 105.

electrolytes or non-electrolytes which, when brought into contact with the cell surface, would reduce the degree of dispersion of the surface colloids. This process is not, however, a simple reciprocal of liquefaction. A *slight* increase in the aggregation of the surface colloids would involve a rise in the viscosity of the cell surface and, if an equilibrium were established, the speed of diffusion of ions and molecules across the cell surface would thus be reduced. As we noted above, the speed of diffusion of any substance across the cell surface is one index of the degree of permeability of the cell for that substance. Hence we may say that with an increase of viscosity at the surface, the permeability of the cell would be decreased. If now the concentration of the agent that is responsible for the increased aggregation at the cell surface were still further increased, there would be an additional increase in the viscosity of the surface. But, as we have already stated, the viscosity of colloids is sharply limited by the state of aggregation of the disperse phase. When the precipitating disperse phase begins to separate out from the dispersion medium, the viscosity suddenly decreases. Similarly, when at the surface of the cell the disperse phase begins to separate from the dispersion medium, *the fluidity of the cell surface* must rise abruptly. The sharp increase in fluidity would obviously involve a sudden removal of the barrier to diffusion for ions and molecules and they would pass the cell surface more rapidly.[9]

From the above considerations it seems, therefore, that the permeability of a cell may be increased either (1) by bringing into contact with the surface a solution of some liquefying agent like a thiocyanate, *i. e.*, some agent that increases the solubility (degree of dispersion) of the surface colloids and the fluidity of the surface, or (2) by bringing into contact with the surface a solution containing an excess of some deliquefying or precipitating agent like $CaCl_2$ which, by increasing the state of aggregation of the surface colloids eventually separates disperse phases from solvent, the fluidity of the cell surface approaching that of the pure dispersion medium.

The normal influences at the cell boundary must have a considerable aggregating effect upon the surface colloids since we do not normally find the cell pigments or other constituents diffusing outwards. Osterhout,[10] furthermore, has shown conclusively that certain electrolytes increase the electrical resistance of a cylinder of *Laminaria* discs. This is to be considered an expression of decreased permeability. These electrolytes ($MgCl_2$, $CaCl_2$, HCl, $La_2(NO_3)_6$) all have, in certain concentrations, a distinct coagulative or dehydrating effect upon a variety of colloids.[11] The effect of $CaCl_2$ is of particular interest since at first it increases the resistance. After a time, however, the resistance again decreases, finally falling below the initial value. This is precisely what we should expect if the effect of the $CaCl_2$ were upon the viscosity of the surface colloids. The theoretical correlation between increased dispersion and increased permeability, as well as that between increased aggregation and initial decreased permeability, is thus actually substantiated by experiment.

Permeability studies upon living cells have brought out one very striking and, at first sight anomalous, fact, viz., for many substances which are not concerned with the normal metabolic processes of the cell, the cell surface is readily permeable, whereas for sugars, salts, amino acids, etc., which must constitute a large proportion of its nutritive material, it is nearly or quite impermeable. The latter substances normally occur, however, within the cell, which forces us to assume that at some previous period the surface must have permitted their passage to the cell interior. This passage to the interior of the cell could have been accomplished only under conditions of increased permeability. Now the cell content is obviously not to be regarded as permanent and fixed and we must account for a mechanism of metabolic interchange. Such a mechanism

9 Ostwald, Wolfg., '11, *Grundriss d. Kolloidchemie*, 2 Aufl., p. 307.

10 Osterhout, W. J. V., '15, Science, 41, 255 for a summary of results.

11 Mines, G., '10, *Jour. of Physiol.*, 40, 327; '11, *ibid.*, 42, 309; Höber, R., u. Spaeth, R. A., '14, *Pflügers Arch.*, 159, 433.

is to be sought in some type of physical-chemical equilibrium that permits the permeability above and below a norm to vary reversibly within definite limits. We have pointed out above that there is in every colloidal system an aggregation or solution equilibrium between disperse phase and dispersion medium. The colloids at the surface of the cell are no exception to this rule. The continued action of a liquefying agent at the cell surface produces a marked increase in permeability and eventually death by irreversible liquefaction. On the other hand, a coagulating agent, *i. e.*, an agent that increases the aggregation of the disperse phases of the surface colloids, produces *at first* a decrease in permeability, but, if the action be sufficiently prolonged, the disperse phases separate out from the dispersion medium and death follows as a result of surface coagulation. Once the disperse phases have begun to separate from the dispersion medium, the fluidity of the cell surface approaches that of the pure dispersion medium which obviously involves a tremendous increase in permeability. Thus cell death, whether by irreversible surface liquefaction or by irreversible surface coagulation, invariably involves an increase in the permeability of the cell. The term "cytolysis" has been loosely applied to cover both cases, though from a physical-chemical standpoint we are dealing with antithetical processes.

The degree of aggregation of the surface colloids, *i. e.*, the degree of intimacy of relation between disperse phases and solvent appears, upon last analysis, to be the critical condition upon which depends the continuation of the cell as a living system. The degree of aggregation of the disperse phases at the surface of the cell is directly dependent upon their solubility in the dispersion medium. This solubility is determined (1) by the concentration, nature and number of electrolytes or organic substances occurring in the liquid phase, and (2) by the temperature of the whole system. We may, therefore, say: (*A*) at the surface of every cell there is a solution equilibrium, a *vital equilibrium*, between disperse phases and solvent; (*B*) the permeability of the cell is determined by the maintenance or shifting of the vital equilibrium.

We may now summarize the foregoing conclusions as follows:

1. In the limiting colloidal system of every cell, whether in the form of a differentiated membrane or not, there exists an equilibrium between disperse phases and dispersion medium.

2. A shifting of this equilibrium in the direction of greater dispersion causes an increased permeability of the cell surface, since the fluidity of the system is increased, the viscosity of the surface is lowered, and a more rapid diffusion occurs across the surface both into and out of the cell.

3. A slight shift of this equilibrium in the direction of increased aggregation involves a solidifying action at the surface, an increased viscosity, a slower rate of diffusion across the surface and a consequent decrease in permeability.

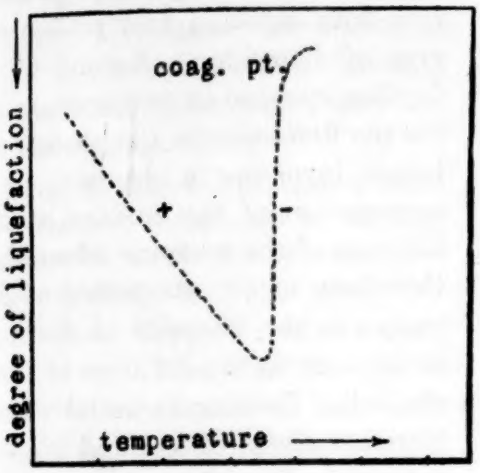
4. A considerable shift of this surface equilibrium in the direction of increased aggregation (insolubility of the surface colloids) involves a decrease in the degree of intimacy between disperse phases and solvent; the fluidity is suddenly increased and diffusion across the surface is correspondingly facilitated.

5. The critical condition of any cell surface, upon which eventually depends the continuation of the cell as a living system, is the state of aggregation of its surface colloids, *i. e.*, the relation of disperse phases to dispersion medium. We may, therefore, speak of a solution equilibrium, a ***vital equilibrium*** at every cell surface, reversible within definite limits, the overstepping of which produces death by surface liquefaction, on the one hand, or by surface coagulation, on the other.

We have thus far considered the cases involving the effects of single electrolytes upon the surface colloids of cells. We shall now briefly consider the physiological effects (1) of combinations of electrolytes and (2) of elevation of temperature.

In any combination of electrolytes it is clear that if it were possible exactly to compensate the dispersion effect of one constituent or

group of constituents by the aggregation effect of another, the solution equilibrium of the surface colloids of a cell exposed to such a combination would remain unchanged. Stated

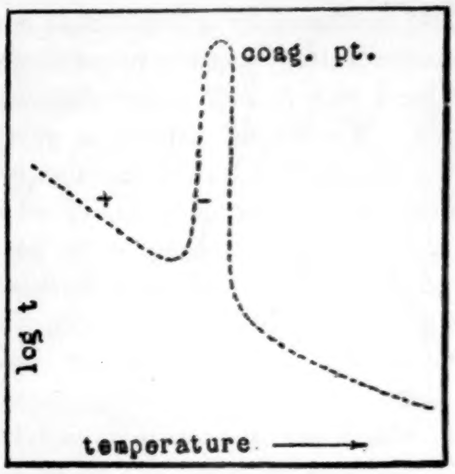


A.

FIG. 1, *A*. An empirical curve representing the liquefying action of atropine upon the melanophores of *Fundulus* at different temperatures. The points are relative. Thus at 22° C. there is more liquefaction than at 10° C., but less than at 36° C. At 37° C. there is again less liquefaction than at 22° C., but more than at 5° C. Up to 36° C. the temperature coefficient of liquefaction is therefore positive, while beyond 36° C. for a few degrees, it becomes negative.

in physiological terms, if we could compensate coagulative and liquefactive forces at the cell surface, the vital equilibrium would remain normal and we should obtain no injurious effect. Compensating effects of this sort are actually realized in solutions like those of Ringer and Locke, or in sea water. We have here a number of combined chemical stimuli which, when acting singly, produce distinct liquefactive or coagulative effects upon living cells, but which, in combination, are relatively harmless. According to the conception of a solution equilibrium at the cell surface, the non-injurious effects of compensated solutions of two or more constituents are to be referred to the failure of these solutions markedly to increase or decrease the solubility of the colloidal disperse phases. Such phenomena of physiological compensation have been collectively termed "antagonisms."

That there is some physical-chemical principle behind all "antagonisms" is strongly suggested (1) by the appearance of the compensation phenomenon between such widely unre-



B.

FIG. 1, *B*. Ostwald's curve showing the effect of elevated temperature upon the viscosity of egg-white. Here the temperature coefficient of liquefaction is positive up to about 57.5° C., while beyond this point to about 60° C. it becomes negative.

A comparison of the two curves shows that above and below a critical point in each system (36° C. and 57.5° C.) the temperature effects are antithetical.

lated chemical substances[12] and (2) by the compensation that appears between liquefying agents and elevated temperature. This last case seems of such importance as to warrant a detailed consideration.

If a colloidal solution of egg-white be gradually heated to 35°–40° C. it becomes slightly less translucent, *i. e.*, there is an increased dispersion. A viscosity measurement[13] shows that an increase in fluidity continues uniformly up to about 57.5° C. At this point there is a sharp reversal of the reaction and the viscosity rises rapidly to about 60.0° C.,

[12] For example "antagonisms" have appeared between various alkaloids such as atropine and eserine, nicotine and curare, between alkaloids and salts as atropine and $CaCl_2$ and $MgCl_2$ and between such salts as KCl and cobalt hexamine chloride (Höber u. Spaeth, *loc. cit.*).

[13] Ostwald, Wo., '13, *Koll. Zeitschr.*, 12, 213.

the coagulation point (Fig. 1, B). Owing to this peculiar property of coagulation, which is, physically, an increase in the state of aggregation, whatever may be the nature of the chemical processes involved, we have here opposite effects produced by a slight and considerable increase in temperature, respectively; the effect of heat may be either liquefactive[14] or coagulative. We should expect, *a priori*, that by adding a powerful liquefying agent to an hydrophilous colloid, the coagulative effect of heat might be overcome wholly or in part, since this would introduce a dispersion factor into the equilibrium. This actually occurs as Pauli[15] and Pauli and Handovsky have shown. Pauli found that upon adding neutral thiocyanates, which are powerful liquefying agents, to egg-albumin, it could not be coagulated even at the boiling point of the mixture.

Four years ago I observed that the liquefying effect of atropine or atropine sulphate upon the melanophores of *Fundulus* could be distinctly reduced by sufficiently elevating the temperature of the solution. Recently[16] I have found that for temperatures up to approximately 36° C., atropine shows a normal positive temperature coefficient, *i. e.*, the liquefying effect increases with a rise in temperature. If, however, we expose contracted melanophores to identical solutions of atropine at 22° C. and at 37° C. for a period of five minutes, the cells from the warm solution show distinctly less liquefaction than those at room temperature. That the cell colloids are not coagulated by the higher temperature is shown by the activity of the cell upon being returned to NaCl or KCl solutions. Thus in this case, for a few degrees, between 36° C. and the elevated coagulation point of the cell protoplasm ($< 43°$ C.) the temperature coefficient of liquefaction for atropine becomes negative (Fig. 1, A). From the foregoing considerations we should expect an elevation in temperature to increase the solubility of the disperse phases at the surface of the melanophore.[17] We have, in addition, the liquefying effect of the atropine. Hence we have here the combined liquefying effect of atropine and elevated temperature, *i. e.*, two forces tending to drive the disperse phases of the cell surface into solution and to increase their degree of dispersion. Beyond 36° C., however, further increase in temperature tends to initiate the first steps in the process of heat coagulation involving a decrease in the state of aggregation of the surface colloids. The inhibition of the atropine effect above 36° C. is, therefore, to be interpreted as due to an elevation in the viscosity of the surface colloids which retards the diffusion of the alkaloid into the cell. Bearing in mind these antithetical physical effects of low and high temperatures, it appears that the experimental data both in the case of colloidal solutions of egg-white and in that of living cells (melanophores) comply well with the theory.[18] A liquefying agent in proper concentration may prevent heat coagulation and, reciprocally, a sufficient elevation in temperature may protect the system against liquefaction.

These physical-chemical relations may offer an explanation of the extraordinary habit of certain blue-green algæ which normally thrive at a temperature of 68° C.[19] The water in which these algæ live contains numerous salts in solution and we suspect at once that among these salts there is a powerful liquefying agent which prevents coagulation by the abnormally high temperature, as in Pauli's experiments upon egg-white. We should expect that a reduction in temperature would prove fatal to such algæ since, under these altered circum-

[14] Lillie, R. S., '15, *Biol. Bulletin*, 28, 260.

[15] Pauli, W., '99, *Pflügers Arch.*, 78, 35; Pauli u. Handovsky, '08, *Hofmeisters Beitr.*, 11, 415.

[16] Unpublished experiments.

[17] It is impossible to carry out an experiment upon the melanophores of *Fundulus* which is directly comparable to Pauli's experiments on the elevated coagulation point of egg-white. KSCN produces a marked liquefaction upon the melanophores, but only after a relatively long exposure (< 30 minutes). Atropine, on the other hand, brings about an irreversible disintegration at room temperature in concentrations of ca. 0.004 *M* in 0.1 *M* NaCl in about five minutes.

[18] See also Lepeschkin, W. W., '11, *Ber. d. deutsch. bot. Gesellsch.*, 29, 247; '13, *ibid.*, 30, 703.

[19] Setchell, W. A., '03, SCIENCE, 17, 943.

stances, the liquefying agent would be free to act. So far as we know no experiments of this sort have ever been performed, though it may be significant that Setchell failed to find any algæ growing at 43°–45° C.

In a recent paper Osterhout[20] advances the hypothesis that substances which increase permeability antagonize those which decrease permeability. He says (p. 256):

> It seems to the writer that the hypothesis offers a rational explanation of antagonism by showing that salts antagonize each other because they produce opposite effects upon the protoplasm.

The nature of these "opposite effects upon the protoplasm" is an increase or decrease of permeability. Osterhout makes no statement as to the meaning of the term "permeability" which, without further qualification, is noncommittal, nor to the *cause* of the permeability changes. With these two fundamental gaps in the theory it seems a far cry to a "rational explanation of antagonism." We have emphasized above that a study of Osterhout's data indicates a direct correlation between decreased permeability and increased surface viscosity. It seems highly probable, however, that all substances producing an initial decrease in permeability will, if allowed to act long enough or in sufficient concentration eventually cause an *increase* in permeability.[21] This conclusion, which we are forced to make from a study of the phenomena of viscosity changes in colloids, complies very well with the experimental data upon permeability changes in both plant and animal cells.

All physical and chemical agents acting upon a colloidal system influence the state of aggregation of the disperse phase, tending either to increase or to decrease the degree of dispersion. Since we have a colloidal system at the surface of every cell, all physical and chemical agents influence the state of aggregation or its equivalent, the solubility of the surface disperse phases in one of two ways, viz., (1) there may be an increase in the degree of dispersion and a corresponding increase in the solubility of the disperse phases and the fluidity of the cell surface, or (2) there may be a decrease in the degree of dispersion or a decreased solubility of the disperse phases which eventually results in a precipitation or coagulation. An "antagonism" is to be considered a physiological compensation of a force favoring dispersion (solubility) by a second force favoring aggregation (insolubility). This relation is reciprocal.

[20] Osterhout, *loc. cit.*

[21] Osterhout calls attention to this fact, but offers no explanation for it.

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SPECIAL ARTICLES

NATURAL CROSS-POLLINATION IN THE TOMATO

Evidence concerning the amount of natural cross-pollination in the tomato has been secured by interplanting two commercial varieties of tomatoes, one a standard and the other a dwarf variety. The difference in habit of growth between these varieties is quite distinct in the early seedling stage. The standard is almost completely dominant over the dwarf type of growth. Any pollen from a standard plant fertilizing a dwarf plant should result in a standard plant in the first generation. To test this point a number of dwarf and standard plants were set three feet apart alternately. They were at least five hundred yards removed from any other dwarf tomatoes. These plants were allowed to set fruit normally and seed was saved from the dwarf plants as the fruit ripened. The dates on which the ripe fruit was gathered correspond approximately to the order in which the flowers were fertilized. Seed from these "open-pollinated" dwarf plants was planted in flats in the greenhouse. The number of standard plants which could be plainly distinguished after six weeks' growth was determined and tabulated.

The approximately two per cent. of crossed plants does not represent all the crossing which might have taken place. Aside from a slightly greater distance, there was an equal chance for the dwarf plants to be fertilized by pollen from other dwarf plants. This crossing would produce only dwarf plants, and hence would not show.

THE NUMBER OF STANDARD PLANTS PRODUCED FROM SEED OF OPEN-POLLINATED DWARF PLANTS

Date Ripe Fruit Gathered	Number of Plants Grown	Number of Standard Plants	Number of Dwarf Plants	Per Cent. of Standard Plants
August 10	935	28	907	2.99
" 21	61	0	61	0.00
" 27	128	1	127	0.78
September 4...	51	1	50	1.96
" 22...	995	13	982	1.31
Total	2,170	43	2,127	1.98

Whether or not cross-pollination is caused by wind or insects is not known, although no large insects, such as bees, were seen to visit the plants. Moreover, tomato pollen is dry and seems better adapted to wind transportation. This could be easily tested by screening the dwarf plants. This would not preclude the possibility of cross-pollination by thrips.

Flowers which are bagged in the bud stage and left undisturbed usually do not set fruit. Jarring the plant while the anthers are dehiscing generally suffices to cause pollination. Tomatoes in greenhouses do not set fruit well unless artificially pollinated.

It seems from this evidence that the tomato is naturally only slightly cross-fertilized. Some external agency, however, is generally needed for self-pollination as well as for cross-pollination.

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EXPERIMENT STATION

SOCIETIES AND ACADEMIES

THE AMERICAN PHILOSOPHICAL SOCIETY

AT the January meeting of the society held January 7, Professor J. A. Miller, of Swarthmore College, read a paper on "The Determination of the Distances of Stars from Us."

He sketched the attempts of Copernicus, Tycho, Brahé, Bradley and Sir William Herschel to find a sensible stellar parallax. Perhaps the chief reason for desiring a stellar parallax at that time was that it would establish the truth of the Copernican system upon observational rather than theoretical evidence.

Although these men failed in their attempts to determine a parallax it was while making observations for that that Bradley discovered the aberration of light and Herschel established the fact that a physical connection exists between the components of certain double stars.

It was 300 years after Copernicus, more than a century after Bradley and a half century after Herschel before the first sensible parallax of a star was actually found when Bessell found the parallax of 61 Cygni and Henderson a parallax of α Centauri. Bessell completed his observations in 1840 and although astronomers have been working assiduously ever since, reliable parallaxes of only about 400 stars have been determined.

At present eight American observatories are working at the problem under the direction of a committee appointed by the American Astronomical Society. Most of these observatories are applying the photographic method devised by Pritchard, of Oxford. This method has since been refined and improved by various men, most notably perhaps by Schlesinger.

The Sproul Observatory of Swarthmore College is one of the eight observatories mentioned above and is spending most of the energies of its staff in that direction. They have determined in all 16 parallaxes. The program contains:

1. All visual binaries whose orbits are well determined.
2. Those visual binaries, the data concerning which leads us to believe their orbits will be determined in the not very distant future.
3. Some spectroscopic binaries.
4. Some stars of large proper motion.
5. Some stars whose hypothetical parallax is large.
6. Other objects.

Classes 1, 2, 3, receive most attention and the measurements and reductions of 13 stars of Class 1 have been completed.

Though no generalization could be made from so small a number of stars as this, yet so far as can be judged from these 13 stars, the orbits of the binaries are comparable in magnitude to the orbits of the planets. The greatest distance between two components of any double star in this list (τ Cygni) being 32 astronomical units, and the least being four astronomical units for 85 Pegasi.

The combined masses of the two components average larger than the sun. The largest mass being of Lalande 9091, which is 48 times the sun and the smallest being 20 Persei which is 0.26 that of the sun.